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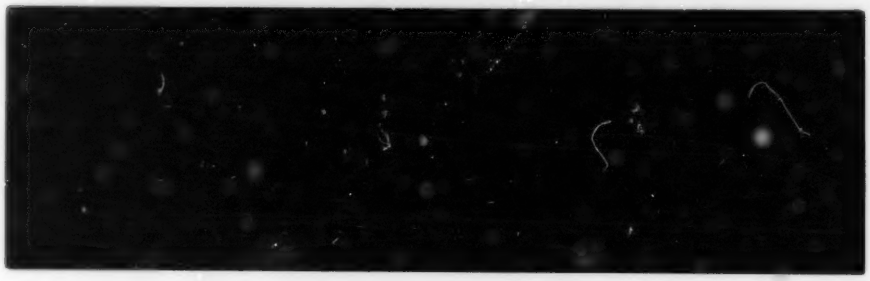

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AN INVESTIGATION INTO THE DUST SETTLING/IMPACTION RATES IN CBDC'S UNDERGROUND COAL MINES

G.W. Bonnell

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AN INVESTIGATION INTO THE DUST SETTLING/IMPACTION RATES IN CBDC'S UNDERGROUND COAL MINES

by

G.W. Bonnell*

ABSTRACT

This report investigates the settling/impaction rates of dust in the return roadways of the Cape Breton Development Corporation's (CBDC) retreat longwall operations. Two surveys were conducted, one at Prince Colliery's 8 West return on November 5, 1989 and the other at Phalen Colliery's 2 West return on December 5, 1989. The information obtained will help management/ventilation officers to determine the optimum location of a remote dust monitoring sensor if a remote dust monitoring system is installed.

Measurements indicated a significant decrease in dust levels as measured from approximately 70 m outbye to the fireseal. This implies that a remote dust monitoring sensor would have to be maintained at or near 70 m outbye (statutory control point) as the wall advanced. If a remote dust monitoring sensor was set up at the fireseal, the measured dust levels would have to be corrected using a predetermined equation.

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ANALYSE DES TAUX DE SÉDIMENTATION ET D'IMPACT DE LA POUSSIÈRE DANS LES MINES DE CHARBON SOUTERRAINES DE LA SDCB

par

G. W. Bonnell*

RÉSUMÉ

Le présent rapport porte sur l'analyse des taux de sédimentation et d'impact de la poussière dans les voies de retour dans les mines exploitées par longues tailles rabattantes de la Société de développement du Cap-Breton (SDCB). On a réalisé deux études, l'une dans la voie de retour 8 Ouest de la houillère Prince, le 5 novembre 1989, et l'autre dans la voie de retour 2 Ouest de la houillère Phalen, le 5 décembre 1989. Les données recueillies aideront les préposés à la gestion/ventilation à déterminer l'endroit optimal pour installer un capteur de télésurveillance de la poussière.

Selon les mesures qui ont été faites, la quantité de poussière diminue considérablement à 70 m environ de la zone hermétique vers le puits. Il faudrait donc, à mesure que le front progresse, maintenir un capteur à une distance de 70 m environ vers le puits (point de contrôle statutaire). Si l'on installait un capteur de télésurveillance de la poussière à l'endroit où se trouve la zone hermétique, il faudrait corriger à l'aide d'une équation prédéterminée les mesures de la quantité de poussière.

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INTRODUCTION

The respirable dust research program of the Cape Breton Coal Research Laboratory (CBCRL) has been described previously (1). The long-term objective of this research program is to lower coal miners' occupational exposure to airborne respirable dust and thus reduce risk of the development and progression of pulmonary disease in coal miners.

With the latest advances in 'real-time' dust monitoring, it has become possible to use 'remote' dust monitoring in addition to the remote monitoring of methane, heat sensors on conveyor systems, carbon monoxide, ventilation, shearers, etc. With routine servicing and calibration, this would enable CBDC to have continuous and instantaneous dust levels for any mining district or location. This information would be much more meaningful and useful as compared to a 'snapshot' of dust conditions that is normally taken during compliance measuring. In addition, claims of high dust levels during any particular shift can be easily verified and remedial measures to improve a 'dusty situation' can be assessed much sooner than is presently possible.

Before such a remote dust monitoring system can be installed, several parameters must be assessed such as reliability, accuracy, robustness, how much servicing and calibration would be required, cost, etc. Another parameter which must be investigated is the determination of where the monitor should be situated, e.g. should it be moved and maintained at the 70 m outbye position of retreating longwall roadways as the face advances or can it be positioned at the fireseal?

The purpose of this report is to address this last question of where the monitor should be situated and to quantify the decrease in dust levels as the ventilation air makes its way out of the district.

The manufacturer for one such remote dust monitoring system has suggested that the respirable dust levels only drop 3-5% over a distance of perhaps 700-900 m, which is bordering on negligible. As will be disclosed in this report, two surveys -- one conducted at 8 West Prince and the other at 2 West Phalen -- indicated that this was not the case, at least for the two CBDC collieries examined.

INSTRUMENTATION

The instrumentation used in obtaining the dust concentrations, expressed in mg/m^3, in this report were: 1) Casella (Rotheroe-Mitchell) SIMPEDS MK2 cyclone sampling heads fitted with Gilian/Dupont constant flow pumps, 2) Hund (real-time) TM-Data dust monitoring systems and 3) Marple cascade impactors (Model 298) fitted with Gilian/Alpha-1 constant flow pumps, Table 1.

CASELLA (ROTHEROE-MITCHELL) SIMPEDS MK2 CYCLONE HEAD FITTED WITH A GILIAN/DUPONT CONSTANT FLOW PUMP

The SIMPEDS MK2 cyclone can be used for both personal sampling and area sampling. Area sampling only was used for the surveys included in this report. The instrument samples 'respirable' dust selectively by a centrifugal separation or removal of the large, fast falling particles, thus collecting only those particles which are normally deposited in the lungs. These larger non-respirable particles are concentrated at the flow periphery where they are separated from the flow and collected in a removable 'grit pot' at the bottom of the cyclone. The smaller respirable particles with less inertia remain in the airstream through the cyclone and are collected on a preweighed filter, enclosed in a reusable cassette (37 mm diameter, 1.5 µm pore size glass fiber filters were used for the surveys included in this report). An electronically controlled constant flow pump with a pulsation damper is used to maintain a smooth flow of 1.9 L/min through the cyclone. The pump motor is driven from a nickel-cadmium rechargeable battery and is intrinsically safe. The weight of respirable particles is obtained by weighing the filter before and after sampling. The weight of the non-respirable particles can be obtained from the 'grit pot' and the combined weights give the total dust (2).

The SIMPEDS cyclones sampling head fitted with a constant flow pump is designed to perform to the specifications provided by the British Medical Research Council's Industrial Pulmonary Disease Committee and by the Johannesburg International Conference on Pneumoconiosis (50% collection of particles with a falling speed equal to that of a 5 micron unit density sphere)(3,4,5). The Casella Type 113A is also designed to these specifications and the two sampling systems have given similar results determined in previous surveys (6).

Table 1 - Field dust surveys instrumentation

Instrumentation for Surveys	Number of Units	Flowrate of Air Sampling System (L/min)
Gilian Constant Flow Pump HFS 113A + Casella SIMPEDS Cyclone	7	1.9
Dupont Constant Flow Pump P2500A + Casella SIMPEDS Cyclone	3	1.9
Hund TM-Data Dust Monitoring System	3	-
Gilian Constant Flow Pump HFS 113A/ Dupont Constant Flow Pump Alpha-1 + Marple Cascade Impactor (Model 298)	2	2.0

HUND TM-DATA DUST MONITORING SYSTEM

The Hund TM-Data is a small highly portable dust monitor which operates on the principle of light-scattering. It can be used for routine checking of dust concentrations and for evaluating anti-dust measures taken in underground and surface working areas.

To measure the dust concentration, the 'Infrared' (IR) beam of a GaAs diode passes through the measuring chamber. The dust particles in the primary beam reflect some of the light. The instrument measures the scattered light deflected by the particles at an angle of 70° to the direction of the primary beam. The use of this scattering angle, combined with a measuring wavelength of 950 nm, allows only those particles which correspond approximately to the probability of deposition of breathable dust (respirable dust) to be detected. Thus the instrument requires no pre-filter or dust separation device since the measuring principle used does not evaluate particles larger than approximately 8 µm (at least theoretically). The scattered light intensity is directly proportional to the dust concentration (7).

Calibration of the instrument for the determination of the dust concentration in mg/m^3 is based on a comparison measurement with a gravimetric dust meter. This initial calibration is done at the factory and a second calibration is done under actual operating conditions based on a comparison measurement with a Casella Type 113A or equivalent, e.g. Casella SIMPEDS cyclone fitted with a constant flow pump.

Power is supplied by a built-in NiCd battery with electronic regulation. The instrument requires no pump as ambient airflow movement is sufficient. Dust concentrations (in the range of 0.00 to 99.99 mg/m^3) are displayed every second. An average dust value is stored in the internal memory of the instrument every 2,4,8,16 or 32 seconds, depending on the overall sampling period. Upon return to the laboratory, the data stored in the internal memory can be transferred via an RS-232 interface to a personal computer for subsequent analysis and for a 'real-time' graphical output of the sampling period (7).

MARPLE CASCADE IMPACTOR (MODEL 298) FITTED
WITH A GILIAN/ALPHA-1 CONSTANT FLOW PUMP

The Marple Cascade Impactor (Model 298) is an eight-stage, radial slot instrument for measuring the size distribution and respirable mass of mine dust. Airflow of 2 L/min is provided by a constant flow pump. The flow enters the inlet cowl and accelerates through the six radial slots in the first impactor stage. Particles larger than the cut-point of the first stage impact on the perforated collection substrate. The airstream then flows through the narrower slots in the second impactor stage, smaller particles impact on the second collection substrate and so on. Prior to sampling each substrate is sprayed with a light coating of grease to enable the dust particles to adhere to the substrate surface and the weight of the dust particles is obtained by weighing the substrate before and after sampling. After the last impactor stage, remaining fine particles are collected on a 34 mm PVC filter (8).

SURVEY PROCEDURES

Dust surveys were conducted at Prince Colliery 8 West return on November 8, 1989 and Phalen Colliery 2 West return on December 5, 1989. Both walls utilized retreat mining methods. On each dust survey, two CBCRL team members travelled underground with the miners on the 7-3 shift. Five sampling stations were selected in each return roadway. Station #1 was at approximately 70 m outbye. Station #5 was setup at the fireseal. Station Nos. 2, 3 and 4 were set up between Station #1 and Station #5 and were approximately equidistant from each other, Figures 1 and 2. Start and stop times of the samplers were noted and recorded. Efforts were made to have the samplers turned on and off as close in time to each other as possible. After the sampling period, all the samplers were collected and the team members returned to the mine surface. Ventilation measurements were also taken during the surveys using standard anemometry techniques.

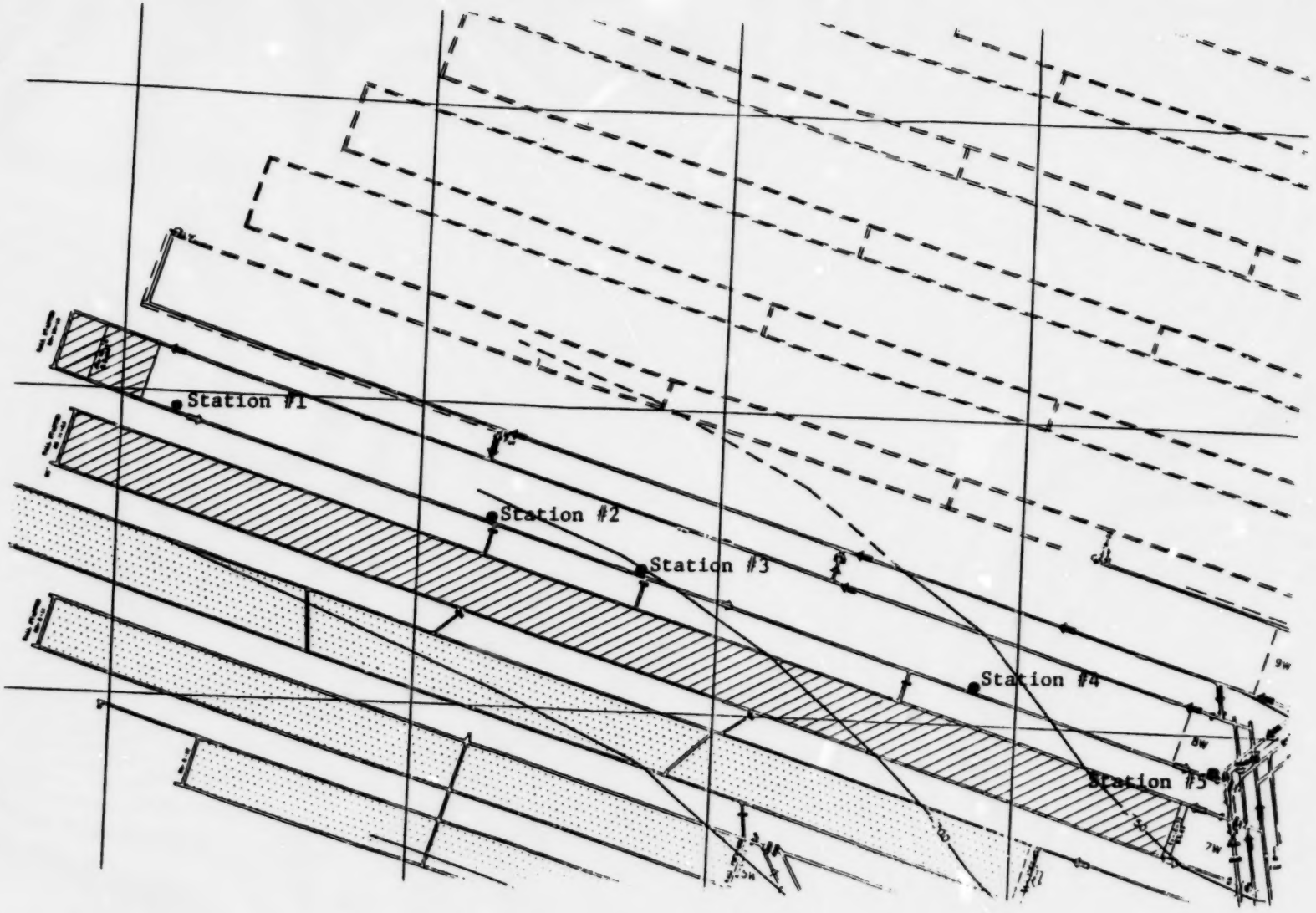

Figure 1 - Sampling stations for Prince 8 West return

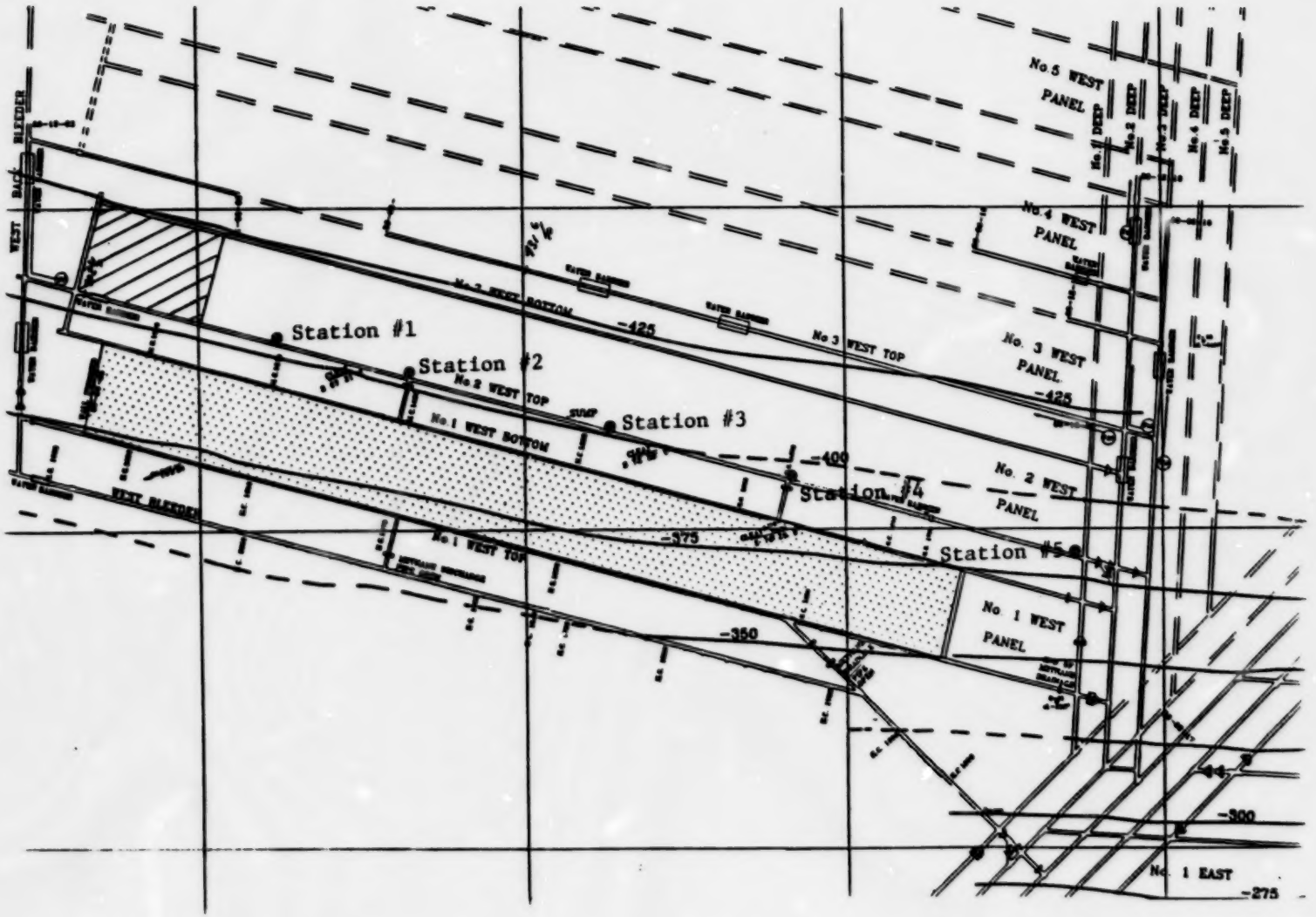

Figure 2 - Sampling stations for Phalen 2 West return

LABORATORY PROCEDURES

Prior to each survey, the constant flow pumps and Hund dust monitors were calibrated. The filters used for the SIMPEDS cyclones and the substrates and filters used with the cascade impactors were weighed using a CAHN C-29 micro-balance. At the end of each survey, the dust monitoring equipment was returned to the laboratory of CBCRL. Flowrates of the samplers were again measured to ensure the flow did not deviate from the original calibration settings. The dust laden filters and substrates were weighed and the net mass of dust on each filter (substrate) was determined. By using the measured net mass of dust on the filter (substrate), flowrate of the constant flow pump and total duration of sampling, mass concentration expressed in mg/m^3 was calculated for each sample (9,10).

The memory unit of each of the Hund dust monitors was 'downloaded' onto an IBM personal computer for subsequent analysis and graphing. Data compilation, tables and graphs were done using "Symphony" spreadsheets/ graphics and "Tech Graph Pad" graphics also on an IBM personal computer.

MEASUREMENT RESULTS

DUST MEASUREMENTS

Tables 2 and 3 provide a summary of the sampling locations, sampling systems, respirable dust weights, elapsed times and respirable dust concentrations for both the Prince and Phalen dust surveys. Figures 3 and 4 show the average respirable dust concentrations of the SIMPEDS cyclones vs distance from original face start for both the Prince and Phalen surveys. Tables 4a and 4b present a summary of the distance from Station #1, average dust concentrations of SIMPEDS cyclones and % respirable dust measured over distance for both the Prince and Phalen dust surveys. A graphical representation of these tables is shown in Figure 5a. In Figure 5b, the same points are plotted, however, a 'second order polynominal' was used to 'curve fit' the data. The equation has the form: $y = a + bx + cx^2$.

Table 2 - Respirable dust concentrations, 8 West return roadway, Prince Colliery, November 8, 1989

Location	Sampling System	Resp. Dust Wt. (mg)	Elapsed Time (min)	Concentration (mg/m^3)
Station #1,	SIMPEDS Cyclone	1.917	258	3.91
70 m outbye	SIMPEDS Cyclone	1.881	258	3.84
	Cascade Impactor-A	2.229	258	4.32
	Hund 671	-	258	2.45
	*Hund 257	-	258	2.89
Station #2,	SIMPEDS Cyclone	1.362	255	2.81
746 m outbye	SIMPEDS Cyclone	1.276	255	2.63
Station #3,	SIMPEDS Cyclone	1.067	253	2.22
1067 m outbye	SIMPEDS Cyclone	1.073	253	2.23
Station #4,	SIMPEDS Cyclone	0.669	251	1.40
1766 m outbye	SIMPEDS Cyclone	0.749	251	1.57
Station #5,	SIMPEDS Cyclone	0.613	249	1.30
2288 m outbye	SIMPEDS Cyclone	0.651	249	1.38
(fireseal)	Cascade Impactor-B	0.534	249	1.07
	Hund 669	-	249	0.65

Table 3 - Respirable dust concentrations, 2 West return roadway, Phalen Colliery, December 5, 1989

Location	Sampling System	Resp. Dust Wt. (mg)	Elapsed Time (min)	Concentration (mg/m^3)
Station #1,	SIMPEDS Cyclone	3.349	277	6.36
118 m outbye	SIMPEDS Cyclone	3.158	277	6.00
	Cascade Impactor-A	2.986	277	5.39
	Hund 671	-	277	3.45
	*Hund 257	-	277	3.88
Station #2,	SIMPEDS Cyclone	2.898	274	5.57
329 m outbye	SIMPEDS Cyclone	2.880	274	5.53
Station #3,	SIMPEDS Cyclone	2.513	271	4.88
649 m outbye	SIMPEDS Cyclone	2.482	271	4.82
Station #4,	SIMPEDS Cyclone	2.141	270	4.17
939 m outbye	SIMPEDS Cyclone	2.160	270	4.21
Station #5,	SIMPEDS Cyclone	1.869	266	3.70
1404 m outbye	SIMPEDS Cyclone	1.830	266	3.62
(fireseal)	Cascade Impactor-B	1.780	266	3.34
	Hund 669	-	266	1.72

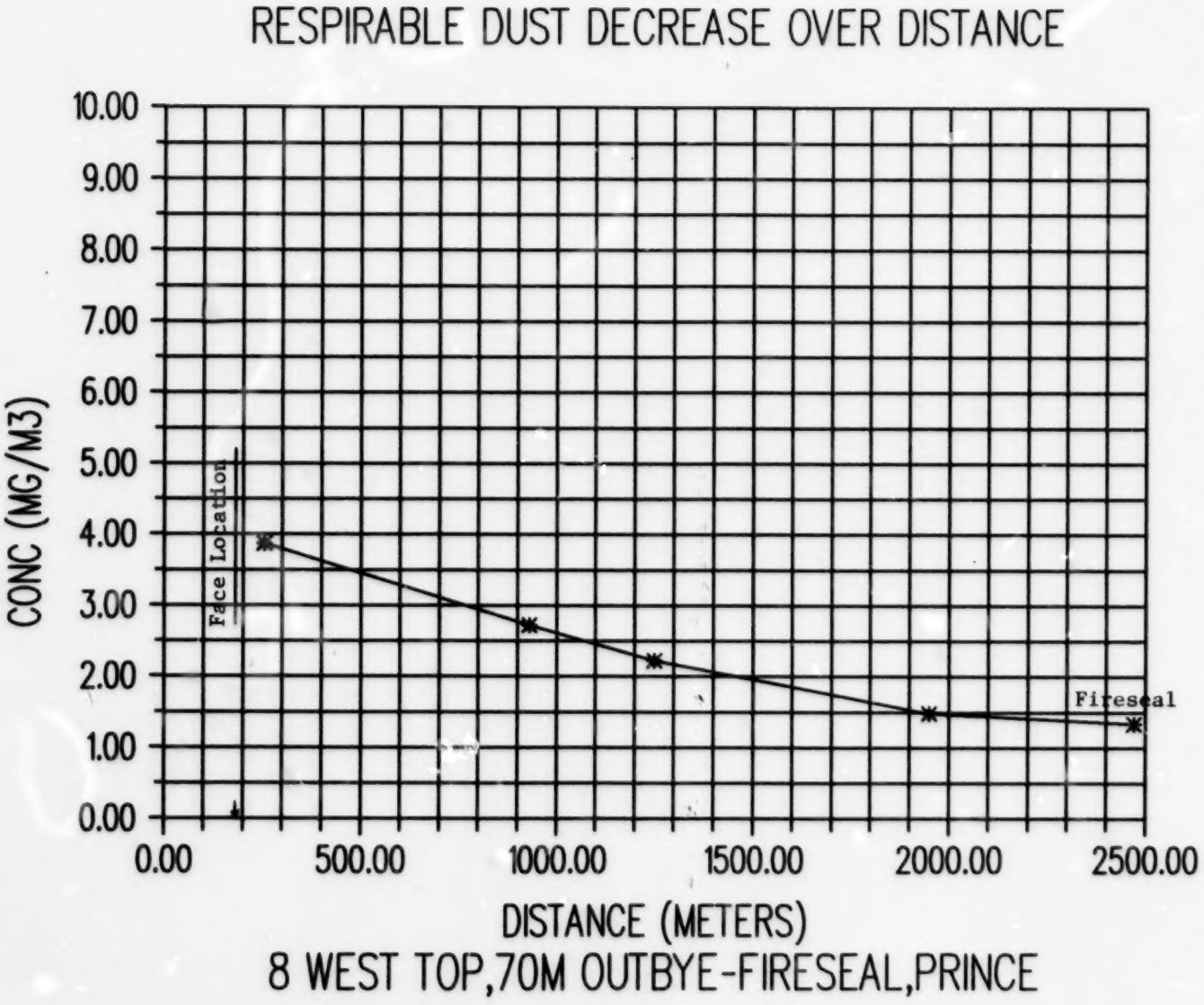

Figure 3 - Decrease in respirable dust over distance, Prince 8 West return roadway

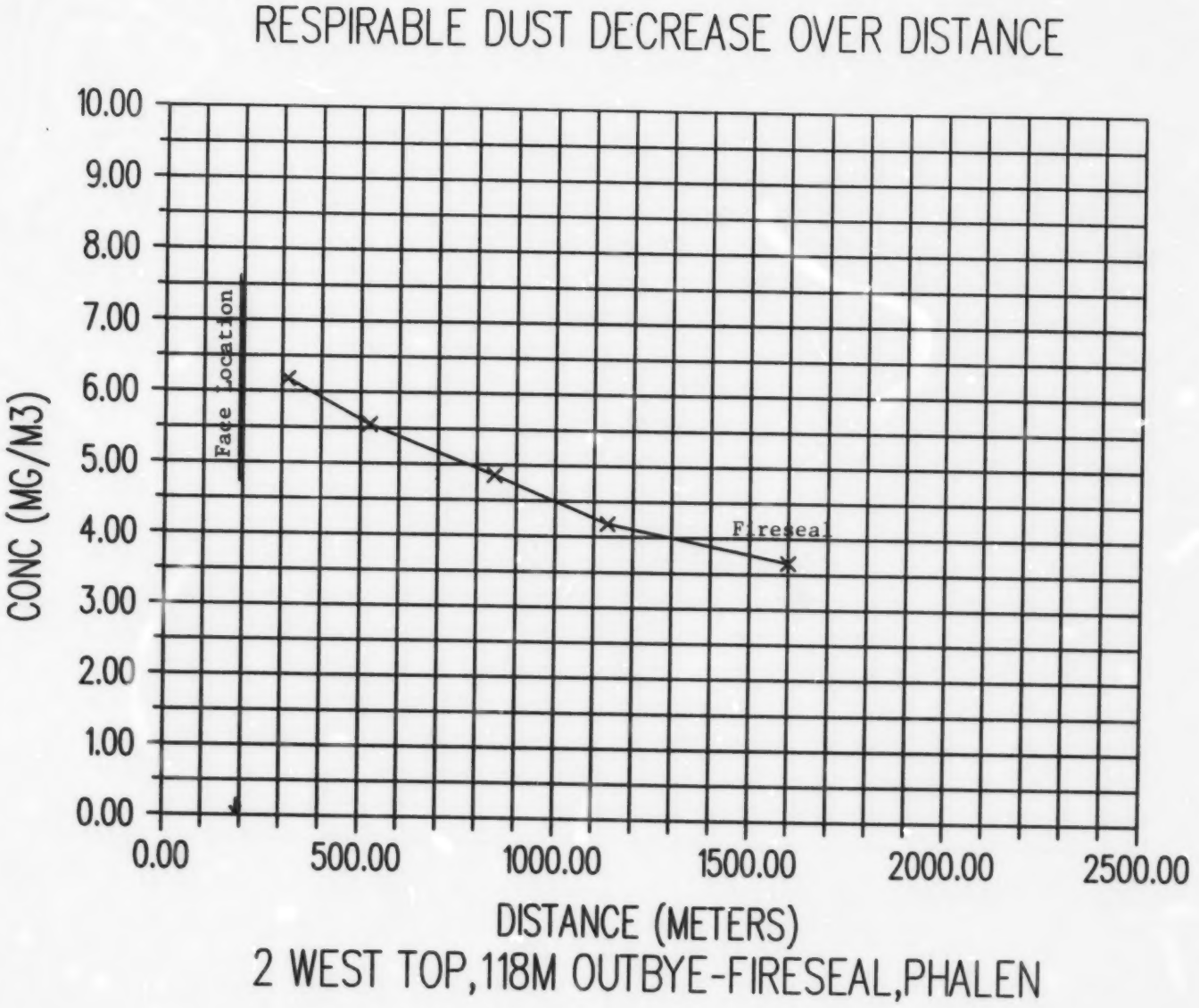

Figure 4 - Decrease in respirable dust over distance, Phalen 2 West return roadway

Table 4a - Average respirable dust concentrations measured using Casella SIMPEDS cyclones, distances from Station #1 and % respirable dust, Prince 8 West return roadway

Distance from Station #1 (m)	(location)	Dust Concentration (mg/m^3)	% Respirable Dust Measured Over Distance
-	(70 m outbye - Station #1)	3.875	100.0
676	(746 m outbye - Station #2)	2.72	70.2
997	(1067 m outbye - Station #3)	2.225	57.4
1696	(1766 outbye - Station #4)	1.485	38.3
2218	(2288 m outbye, fireseal - Station #5)	1.34	34.6

Table 4b - Average respirable dust concentrations measured using Casella SIMPEDS cyclones, distances from Station #1 and % respirable dust, Phalen 2 West return roadway

Distance from Station #1 (m)	(location)	Dust Concentration (mg/m^3)	% Respirable Dust Measured Over Distance
-	(118 m outbye - Station #1)	6.18	100.0
211	(329 m outbye - Station #2)	5.55	89.8
531	(649 m outbye - Station #3)	4.85	78.5
821	(939 m outbye - Station #4)	4.19	67.8
1286	(1404 m outbye, fireseal - Station #5)	3.66	59.2

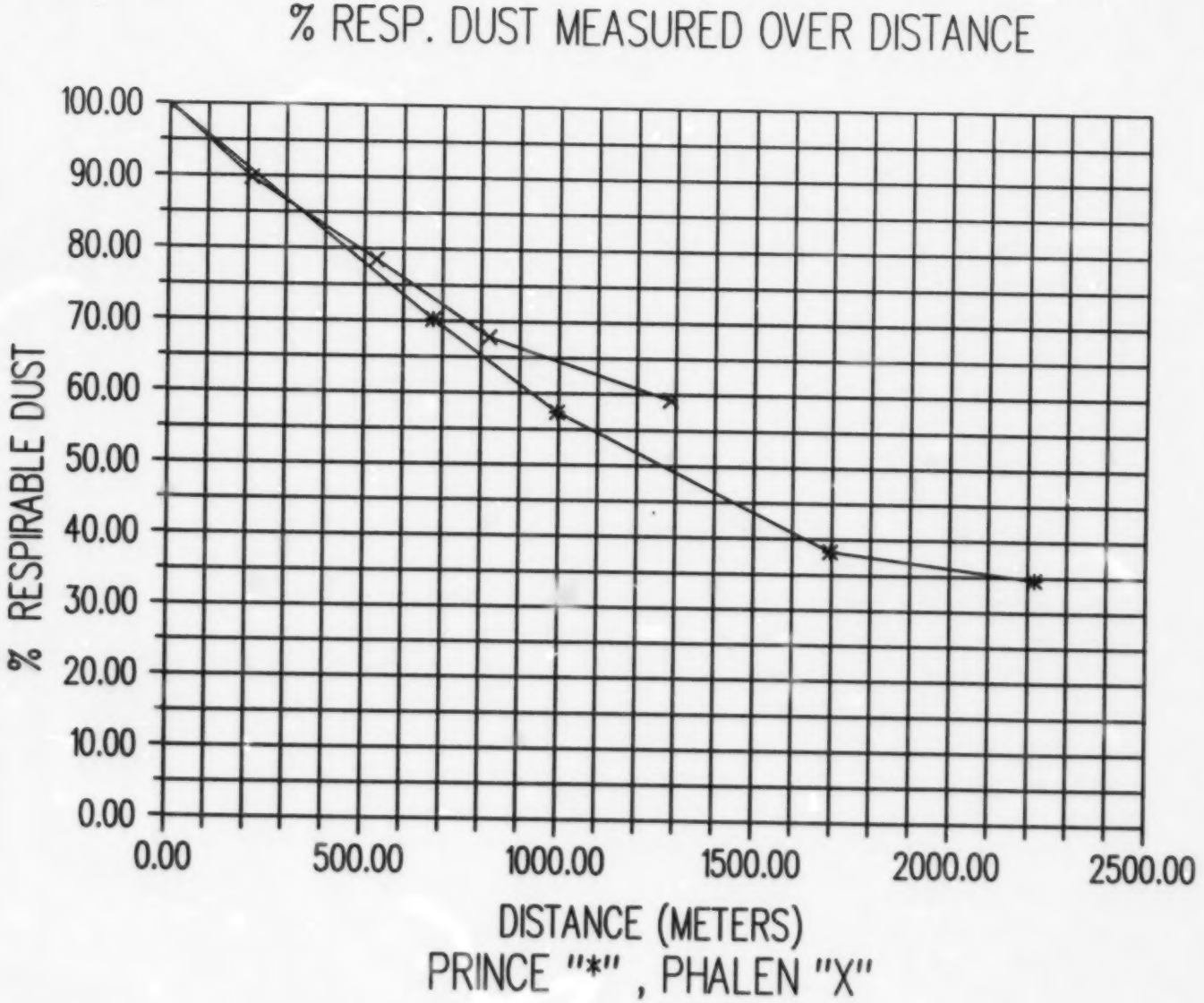

Figure 5a - Percent respirable dust decrease vs distance from Station #1

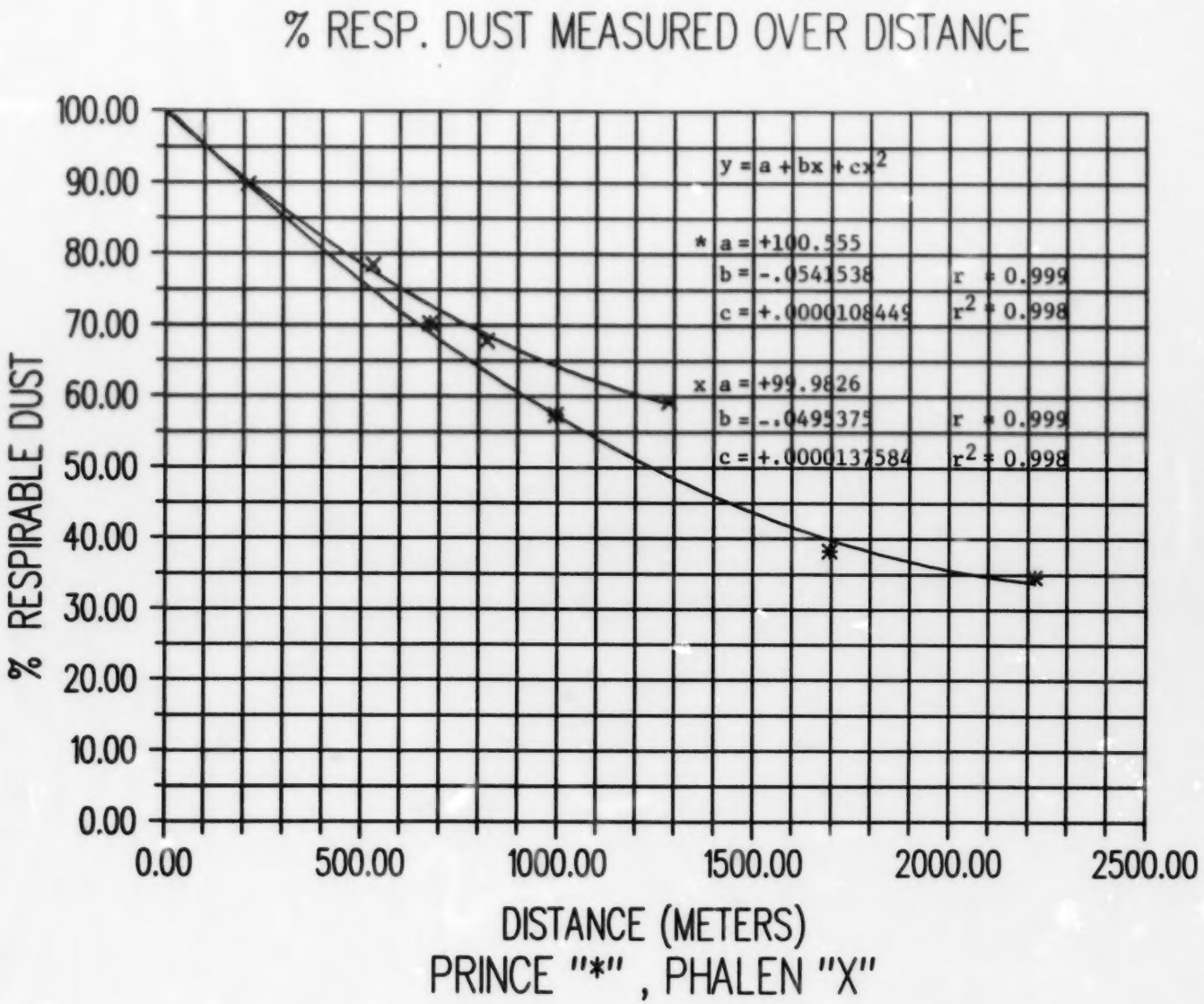

Figure 5b - Percent respirable dust decrease vs distance from Station #1 (second order polynomial curve fit)

		Correlation Coefficients
For Prince	a = 1.00555E + 02	r = 0.999
	b = -5.41538E - 02	r^2 = 0.998
	c = 1.08449E - 05	
For Phalen	a = 9.99826E + 01	r = 0.999
	b = -4.95375E - 02	r^2 = 0.998
	c = 1.37584E - 05	

Tables 5 to 8 present the results obtained from the cascade impactors for Stations #1 and #5 for both the Prince and Phalen dust surveys. The following is a brief description or explanation for several of the parameters in these tables: a) the weight (mass) of the dust collected on each substrate and the filter is under the heading 'Particulate Weight W mg', b) the concentration is calculated for each stage and is given in mg/m^3, c) the stage cut-point Dp in microns indicates particle size distribution, with respirable dust being that dust collected on Stages 5 to 8 plus the filter. This concentration is presented in the information above the table following the title 'Resp. Mass Conc.', d) the 'effectiveness' E for each stage of the cascade impactor is presented under the heading 'Effectiveness at 2.0 L/m E = e(L - f)'. Effectiveness 'E' refers to the sampling efficiency, 'e' is the percentage of particles suspended in the ambient air that actually enters the inlet of the impactor and 'f' is the internal loss or the percentage of particles which enter the inlet and are collected on extraneous internal surfaces, and not on the collection substrates or backup filter and e) the 'corrected particulate weight (mass)' for each stage is found by dividing the weight of the sample on the substrate by the effectiveness E. The corrected total mass concentration and the corrected respirable mass concentration are also presented in the information above the table.

Figures 6 and 7 present the Wt% of dust vs the 'cut-off' in microns (size distribution) for Stations #1 and #5. Figures 8 and 9 present the cumulative % deposition of dust vs 'cut-off' in microns for Stations #1 and #5. Figures 10 and 11 present the corrected dust concentration of each impactor 'stage' vs 'cut-off' in microns for Stations #1 and #5.

Real-time respirable dust concentrations for both surveys using the Hund TM-Data are presented in Figures 12 to 19. These dust concentrations

IMPACTOR DATA WORK SHEET UPDATED TO 14-Nov-89

TEST NO	SURVEY # 48			DATE	NOV 08,1989	GENERAL COMMENTS:
NAME OR LOCATION	8 WEST TOP (RETURN)					
MINE	PRINCE					
LOCATION	70H OUTBYE (STA #1)					
PUMP	A1					
INIT.FLOW	2.00 l/min	FINAL FLOW	1.96 l/min			
NOM. FLOW	2.00 l/min			IMPACTOR MODEL #	MARPLE 298	
START TIME	8.28	508		IMPACTOR SERIAL #	324 (A)	
STOP TIME	12.46	766				
RUN TIME	258 min	MYLAR BLANK	-0.004			
VOLUME	0.516 m3	PVC BLANK	0.011			
TOT.MASS.C	7.87 mg/m3	RESP FRTN'	52.52%	RESP MASS CONC	4.14 mg/m3	
CORRECTED TOT.MASS.C	9.65 mg/m3	RESP FRTN'	44.78%	RESP MASS CONC	4.32 mg/m3	

SUBSTRATE I.D. S-A	STAGE NUMBER	STAGE CUT-POINT Dp (3) microns	INITIAL WEIGHT W1 mg	FINAL WEIGHT W2 mg	(4) PARTICULATE WEIGHT W mg	(5) CONCENTRATION C mg/m3	LOG 10 Dp	(6) ^LOG 10 Dp	^C/^LOG 10 Dp mg/m3/log micron	(8) G.M.D. microns	W/W TOTAL %	% < Dp	EFFICTIVENESS AT 2.0 l/min E=e(1-f) (9)	CORRECTED PARTICULATE WEIGHT Wc (10)	TECHNICAL ERROR COMMENTS
2014	1	21	23.456	23.853	0.401	0.78	1.322	0.377	2.1	32.4	9.87%	90.13%	0.52	0.771	
2015	2	15	23.399	23.742	0.347	0.67	1.176	0.146	4.6	17.7	8.54%	81.59%	0.61	0.569	
2016	3	10	23.055	23.566	0.515	1.00	1.000	0.176	5.7	12.2	12.68%	68.91%	0.78	0.660	
2017	4	6	23.475	24.137	0.666	1.29	0.778	0.222	5.8	7.7	16.39%	52.52%	0.89	0.748	
2018	5	3.5	23.485	24.571	1.090	2.11	0.544	0.234	9.0	4.6	26.83%	25.70%	0.95	1.147	
201v	6	2	23.243	23.978	0.739	1.43	0.301	0.243	5.9	2.6	18.19%	7.51%	0.96	0.770	
2020	7	0.9	23.507	23.703	0.200	0.39	-0.046	0.347	1.1	1.3	4.92%	2.58%	0.97	0.206	
2021	8	0.5	23.621	23.691	0.074	0.14	-0.301	0.255	0.6	0.7	1.82%	0.76%	0.99	0.075	
2022	FILTER	0.25	10.242	10.284	0.031	0.06	-0.602	0.301	0.2	0.4	0.76%	-0.00%	1.00	0.031	
	TOTAL WEIGHT	-	-	-	4.063	7.87	-	-	-	-	100.00%	-	-	4.978	

NOTES: (1) V=RUN TIME * FLOW (2) C TOT=W TOT/V (3) GIVEN FOR 2.0 l/min

(4) W = W2 - W1 (5) ^C=W/V (6) ^LOG 10 Dp = LOG 10 Dp (i-1) - LOG 10 Dp (i)

(7) W TOT = SUM OF PARTICULATE MATTER INCLUDING BACKUP FILTER

(8) GMD= $\sqrt{Dp\ (i) * Dp\ (i-1)}$

(9) E=e(1-f) where e is sampling efficiency and f is internal loss

(10) Wc=W/E

Dp 0 is the largest particle size sampled. If not known, you can use Dp 0 = 50 microns. By convention the minimum diameter for the filter stage is assigned a value one half that of the last impactor stage.

Table 5 - Particle size distribution using a Cascade Impactor - Station #1, Prince 8 West return, November 8, 1989

IMPACTOR DATA WORK SHEET UPDATED TO 14-Nov-89

TEST NO	SURVEY # 48			DATE	NOV 08,1989	GENERAL COMMENTS:	
NAME OR LOCATION	8 WEST TOP (RETURN)						
MINE	PRINCE						
LOCATION	FIRESEAL (STA #5)						
PUMP	G2						
INIT.FLOW	2.00 l/min	FINAL FLOW	2.00 l/min				
NOM. FLOW	2.00 l/min			IMPACTOR MODEL #	MARPLE 298		
START TIME	9.10	550		IMPACTOR SERIAL #	334 (B)		
STOP TIME	15.19	799					
RUN TIME	249 min	MYLAR BLANK	-0.004				
VOLUME	0.498 m3	PVC BLANK	0.011				
TOT.MASS.C	1.38 mg/m3	RESP FRTN'	74.75%	RESP MASS CONC	1.03 mg/m3		
CORRECTED TOT.MASS.C	1.72 mg/m3	RESP FRTN'	62.31%	RESP MASS CONC	1.07 mg/m3		

SUBSTRATE I.D. S-8	STAGE NUMBER	STAGE CUT-POINT Dp (3) microns	INITIAL WEIGHT W1 mg	FINAL WEIGHT W2 mg	(4) PARTICULATE WEIGHT W mg	(5) CONCENTRATION C mg/m3	(6) LOG 10 Dp	(6) ^LOG 10 Dp	^C/^LOG 10 Dp mg/m3/log micron	(8) G.M.D. microns	W/W TOTAL %	% < Dp	EFFICTIVENESS AT 2.0 l/min E=e(1-f) (9)	CORRECTED PARTICULATE WEIGHT Wc (10)	TECHNICAL ERROR COMMENTS
2023	1	21	23.675	23.816	0.145	0.29	1.322	0.377	0.8	32.4	21.04%	78.96%	0.52	0.279	
2024	2	15	22.983	23.081	0.022	0.04	1.176	0.146	0.3	17.7	3.19%	75.76%	0.61	0.036	
2025	3	10	23.298	23.296	0.002	0.00	1.000	0.176	0.0	12.2	0.29%	75.47%	0.78	0.003	
2026	4	6	23.388	23.389	0.005	0.01	0.778	0.222	0.0	7.7	0.73%	74.75%	0.89	0.006	
2027	5	3.5	23.222	23.316	0.098	0.20	0.544	0.234	0.8	4.6	14.22%	60.52%	0.95	0.103	
2028	6	2	23.492	23.752	0.264	0.53	0.301	0.243	2.2	2.6	38.32%	22.21%	0.96	0.275	
2029	7	0.9	23.403	23.478	0.079	0.16	-0.046	0.347	0.5	1.3	11.47%	10.74%	0.97	0.081	
2030	8	0.5	23.686	23.732	0.050	0.10	-0.301	0.255	0.4	0.7	7.26%	3.48%	0.99	0.051	
2031	FILTER	0.25	10.075	10.110	0.024	0.05	-0.602	0.301	0.2	0.4	3.48%	0.00%	1.00	0.024	
	TOTAL WEIGHT	-	-	-	0.689	1.38	-	-	-	-	100.00%	-	-	0.857	

NOTES:

(1) V=RUN TIME * FLOW

(2) C TOT=W TOT/V

(3) GIVEN FOR 2.0 l/min

(4) W = W2 - W1

(5) ^C=W/V

(6) ^LOG 10 Dp = LOG 10 Dp (i-1) - LOG 10 Dp (i)

(7) W TOT = SUM OF PARTICULATE MATTER INCLUDING BACKUP FILTER

(8) GMD= $\sqrt{Dp\ (i) * Dp\ (i-1)}$

(9) E=e(1-f) where e is sampling efficiency and f is internal loss

(10) Wc=W/E

Dp 0 is the largest particle size sampled. If not known, you can use Dp 0 = 50 microns. By convention the minimum diameter for the filter stage is assigned a value one half that of the last impactor stage.

Table 6 - Particle size distribution using a Cascade Impactor - Station #5, Prince 8 West return, November 8, 1989

IMPACTOR DATA WORK SHEET UPDATED TO 07-Dec-89

TEST NO — SURVEY # 49 — DATE DEC 05,1989

NAME OR LOCATION — 2 WEST TOP (RETURN)

MINE — PHALEN

LOCATION — 11BH OUTBYE (STA #1)

PUMP — A1

INIT.FLOW 2.00 l/min — FINAL FLOW 2.03 l/min

NOM. FLOW 2.00 l/min

START TIME 8.05 — 485

STOP TIME 12.42 — 762

RUN TIME 277 min — MYLAR BLANK -0.018

VOLUME 0.554 m3 — PVC BLANK 0.015

TOT.MASS.C 12.58 mg/m3 — RESP FRTN' 41.06% — RESP MASS CONC 5.17 mg/m3

CORRECTED TOT.MASS.C 15.37 mg/m3 — RESP FRTN' 35.07% — RESP MASS CONC 5.39 mg/m3

IMPACTOR MODEL # MARPLE 298

IMPACTOR SERIAL # 324 (A)

GENERAL COMMENTS: UNABLE TO SET UP DUST MONITORS AT 70N OUTBYE DUE TO TRANSFORMERS AND EQUIPMENT IN THE WAY ALSO, THERE WAS A LOT OF WATER AT THIS LOCATION

SUBSTRATE I.D. S-A	STAGE NUMBER	STAGE CUT-POINT Dp (3) microns	INITIAL WEIGHT W1 mg	FINAL WEIGHT W2 mg	(4) PARTICULATE WEIGHT W mg	(5) CONCENTRATION 'C mg/m3	LOG 10 Dp	(6) 'LOG 10 Dp	'C/'LOG 10 Dp mg/m3/log micron	(8) G.M.D. microns	W/W TOTAL %	% < Dp	EFFICTIVENESS AT 2.0 l/min E=e(1-f) (9)	CORRECTED PARTICULATE WEIGHT Wc (10)	TECHNICAL ERROR COMMENTS
2050	1	21	23.637	24.065	0.446	0.81	1.322	0.377	2.1	32.4	6.40%	93.60%	0.52	0.858	
2051	2	15	23.652	24.305	0.671	1.21	1.176	0.146	8.3	17.7	9.63%	83.98%	0.61	1.100	
2052	3	10	23.715	25.023	1.326	2.39	1.000	0.176	13.6	12.2	19.02%	64.95%	0.78	1.700	
2053	4	6	23.723	25.371	1.666	3.01	0.778	0.222	13.6	7.7	23.90%	41.06%	0.89	1.872	
2054	5	3.5	23.349	24.893	1.562	2.82	0.544	0.234	12.0	4.6	22.41%	18.65%	0.95	1.644	
2055	6	2	23.604	24.213	0.627	1.13	0.301	0.243	4.7	2.6	8.99%	9.65%	0.96	0.653	
2056	7	0.9	23.138	23.561	0.441	0.80	-0.046	0.347	2.3	1.3	6.33%	3.33%	0.97	0.455	
2057	8	0.5	23.774	23.967	0.211	0.38	-0.301	0.255	1.5	0.7	3.03%	0.30%	0.99	0.213	
2058	FILTER	0.25	16.718	16.754	0.021	0.04	-0.602	0.301	0.1	0.4	0.30%	0.00%	1.00	0.021	
	TOTAL WEIGHT	-	-	-	6.971	12.58	-	-	-	-	100.00%	-	-	8.516	

NOTES:

(1) V=RUN TIME * FLOW

(2) C TOT=W TOT/V

(3) GIVEN FOR 2.0 l/min

(4) W = W2 - W1

(5) 'C=W/V

(6) 'LOG 10 Dp = LOG 10 Dp (i-1) - LOG 10 Dp (i)

(7) W TOT = SUM OF PARTICULATE MATTER INCLUDING BACKUP FILTER

(8) GMDi= $\sqrt{Dp\,(i) * Dp\,(i-1)}$

(9) E=e(1-f) where e is sampling efficiency and f is internal loss

(10) Wc=W/E

Dp 0 is the largest particle size sampled. If not known, you can use Dp 0 = 50 microns. By convention the minimum diameter for the filter stage is assigned a value one half that of the last impactor stage.

Table 7 - Particle size distribution using a Cascade Impactor - Station #1, Phalen 2 West return, December 5, 1989

IMPACTOR DATA WORK SHEET UPDATED TO 07-Dec-89

TEST NO		SURVEY # 49			DATE	DEC 05,1989	GENERAL COMMENTS: DUST MONITORS SET UP 16 ARCHES INBYE FROM THE FIRESEAL
NAME OR LOCATION		2 WEST TOP (RETURN)					
MINE		PHALEN					
LOCATION		FIRESEAL (STA #5)					
PUMP		G2					
INIT.FLOW	2.00	l/min	FINAL FLOW	2.02 l/min			
NOM. FLOW	2.00	l/min					
START TIME	8.38		518		IMPACTOR MODEL #	MARPLE 298	
STOP TIME	13.04		784		IMPACTOR SERIAL #	334 (B)	
RUN TIME	266	min	MYLAR BLANK	-0.018			
VOLUME	0.532	m3	PVC BLANK	0.015			
TOT.MASS.C	4.52	mg/m3	RESP FRTN'	70.92%	RESP MASS CONC	3.20 mg/m3	
CORRECTED TOT.MASS.C	5.10	mg/m3	RESP FRTN'	65.54%	RESP MASS CONC	3.34 mg/m3	

SUBSTRATE I.D. S-8	STAGE NUMBER	STAGE CUT-POINT Dp (3) microns	INITIAL WEIGHT W1 mg	FINAL WEIGHT W2 mg	(4) PARTICULATE WEIGHT W mg	(5) CONCENTRATION 'C mg/m3	LOG 10 Dp	(6) 'LOG 10 Dp	'C/'LOG 10 Dp mg/m3/log micron	(8) G.M.D. microns	W/W TOTAL %	% < Dp	EFFICTIVENESS AT 2.0 l/min E=e(1-f) (9)	CORRECTED PARTICULATE WEIGHT Wc (10)	TECHNICAL ERROR COMMENTS
2059	1	21	24.049	24.116	0.085	0.16	1.322	0.377	0.4	32.4	3.54%	96.46%	0.52	0.163	
2060	2	15	24.637	24.725	0.106	0.20	1.176	0.146	1.4	17.7	4.41%	92.05%	0.61	0.174	
2061	3	10	23.689	23.846	0.175	0.33	1.000	0.176	1.9	12.2	7.28%	84.78%	0.78	0.224	
2062	4	6	23.972	24.287	0.333	0.63	0.778	0.222	2.8	7.7	13.85%	70.92%	0.89	0.374	
2063	5	3.5	23.609	24.439	0.848	1.59	0.544	0.234	6.8	4.6	35.27%	35.65%	0.95	0.893	
2064	6	2	24.337	24.920	0.601	1.13	0.301	0.243	4.6	2.6	25.00%	10.65%	0.96	0.626	
2065	7	0.9	23.551	23.660	0.127	0.24	-0.046	0.347	0.7	1.3	5.28%	5.37%	0.97	0.131	
2066	8	0.5	23.656	23.720	0.082	0.15	-0.301	0.255	0.6	0.7	3.41%	1.96%	0.99	0.083	
2067	FILTER	0.25	16.317	16.379	0.047	0.09	-0.602	0.301	0.3	0.4	1.96%	-0.00%	1.00	0.047	
	TOTAL WEIGHT	-	-	-	2.404	4.52	-	-	-	-	100.00%	-	-	2.715	

NOTES: (1) V=RUN TIME * FLOW (2) C TOT=W TOT/V (3) GIVEN FOR 2.0 l/min

(4) W = W2 - W1 (5) 'C=W/V (6) 'LOG 10 Dp = LOG 10 Dp (i-1) - LOG 10 Dp (i)

(7) W TOT = SUM OF PARTICULATE MATTER INCLUDING BACKUP FILTER

(8) GMDi= $\sqrt{Dp\ (i) * Dp\ (i-1)}$

(9) E=e(1-f) where e is sampling efficiency and f is internal loss

(10) Wc=W/E

Dp 0 is the largest particle size sampled. If not known, you can use Dp 0 = 50 microns. By convention the minimum diameter for the filter stage is assigned a value one half that of the last impactor stage.

Table 8 - Particle size distribution using a Cascade Impactor - Station #5, Phalen 2 West return, December 5, 1989

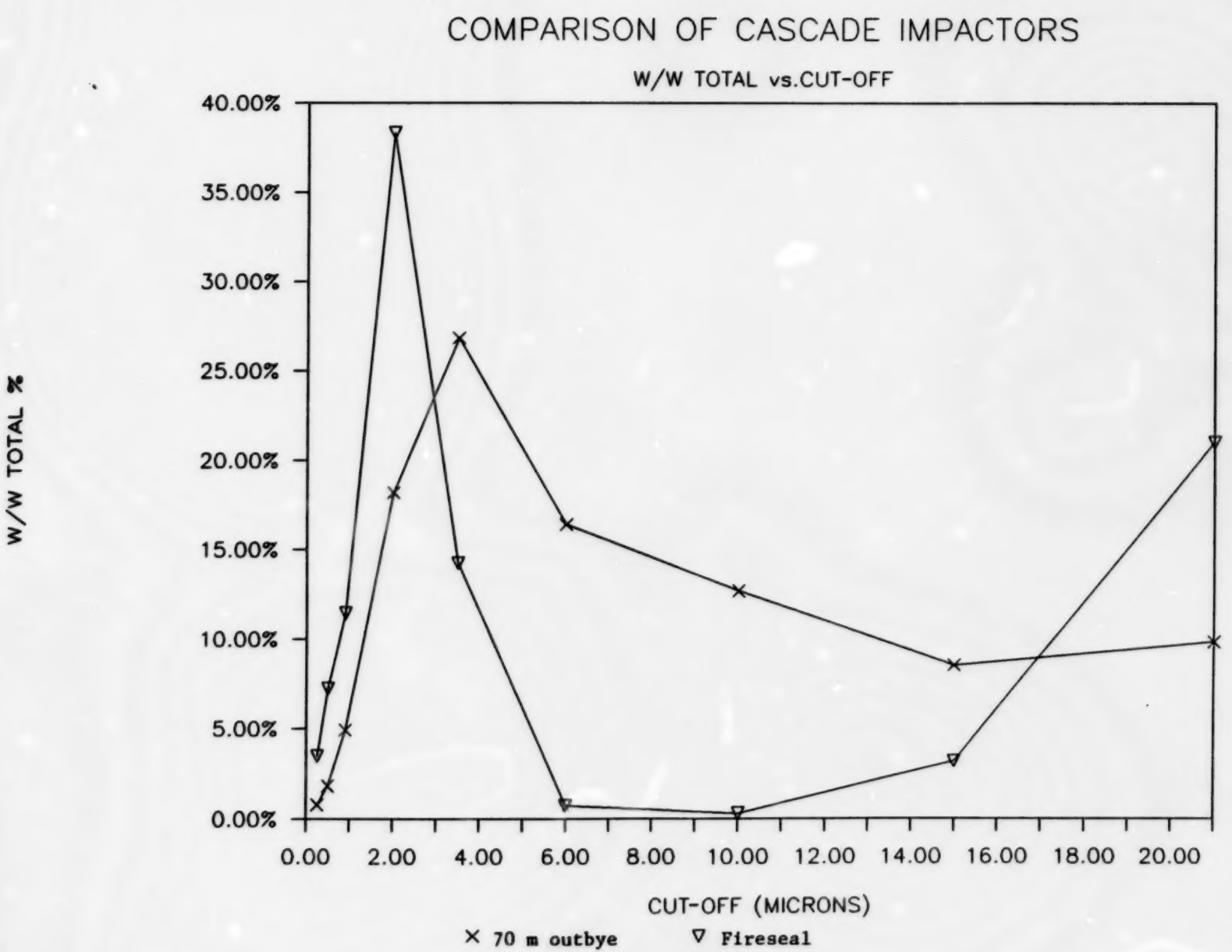

Figure 6 - Weight % of dust vs 'cut-off' for the Cascade Impactors - Prince 8 West return, November 8, 1989

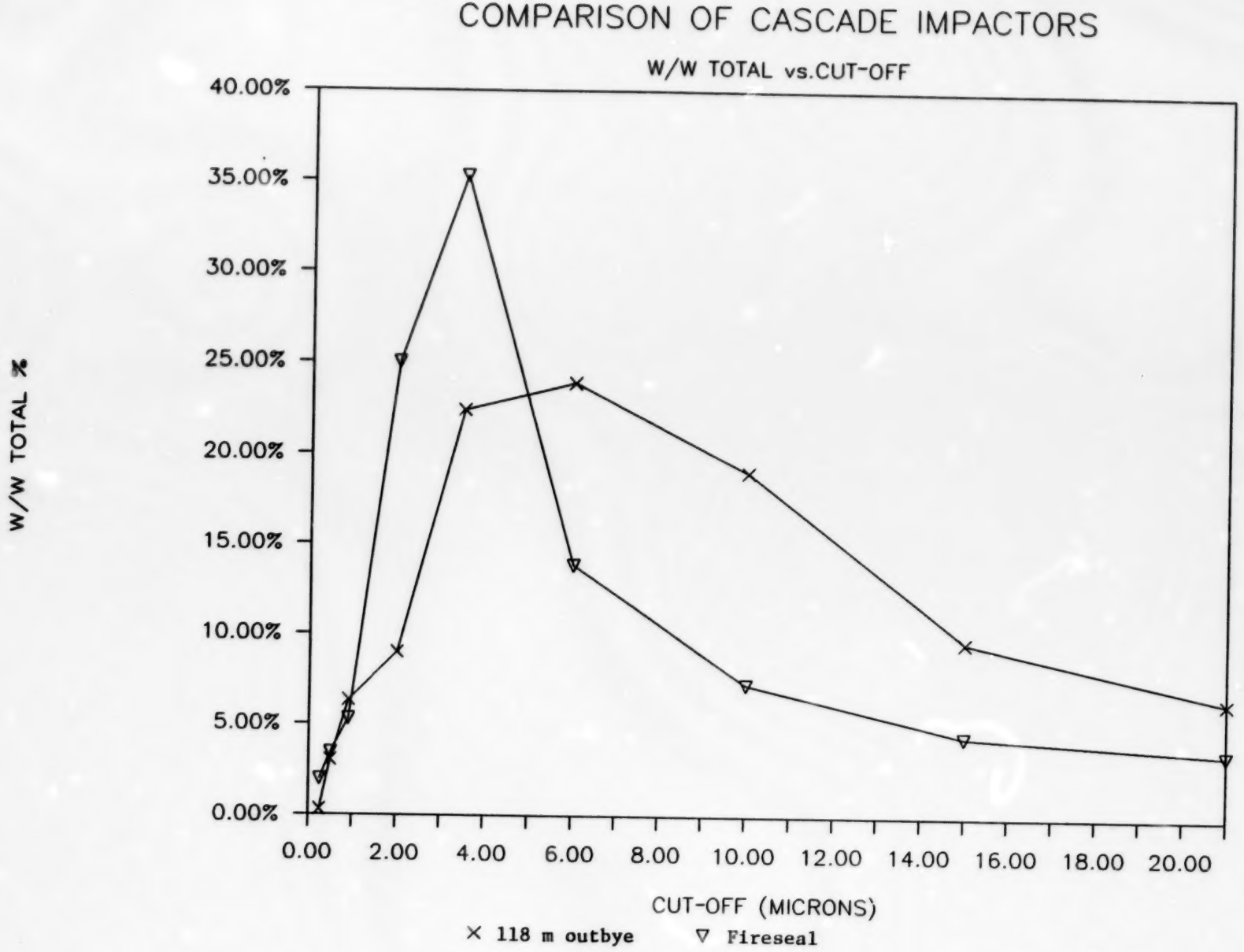

Figure 7 - Weight % of dust vs 'cut-off' for the Cascade Impactors - Phalen 2 West return, December 5, 1989

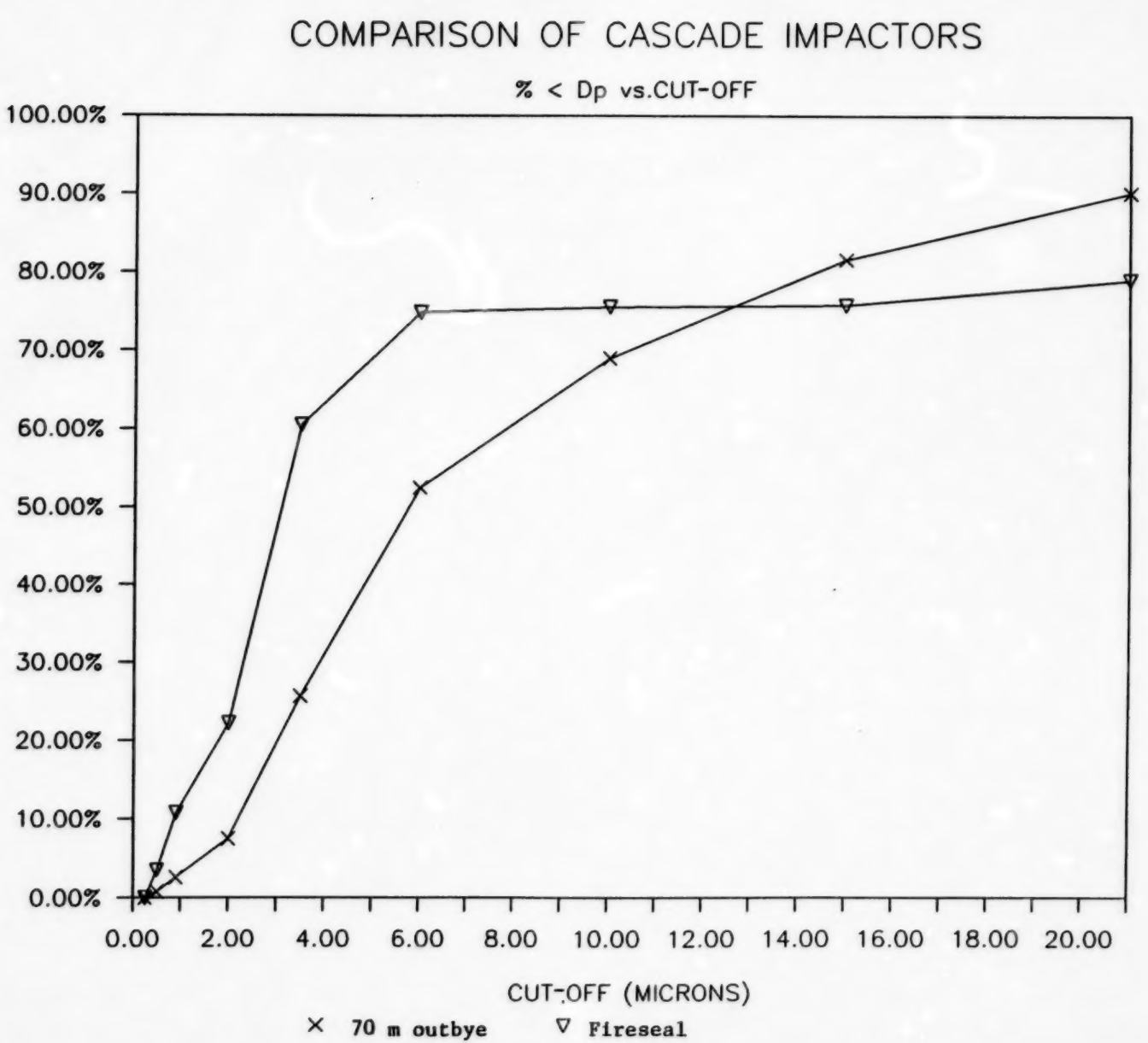

Figure 8 - Cumulative % deposition of dust vs 'cut-off' for the Cascade Impactors - Prince 8 West return, November 8, 1989

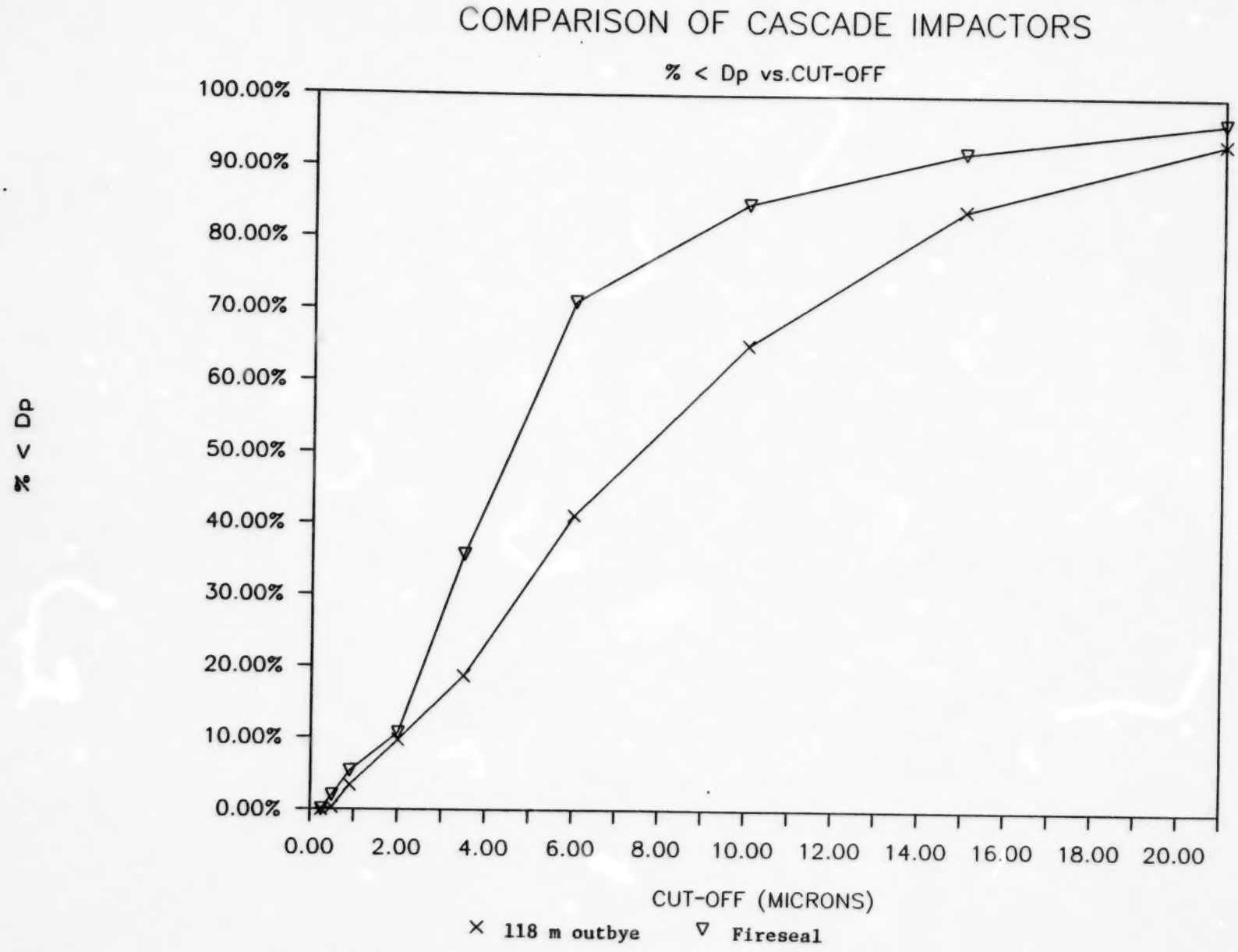

Figure 9 - Cumulative % deposition of dust vs 'cut-off' for the Cascade Impactors - Phalen 2 West return, December 5, 1989

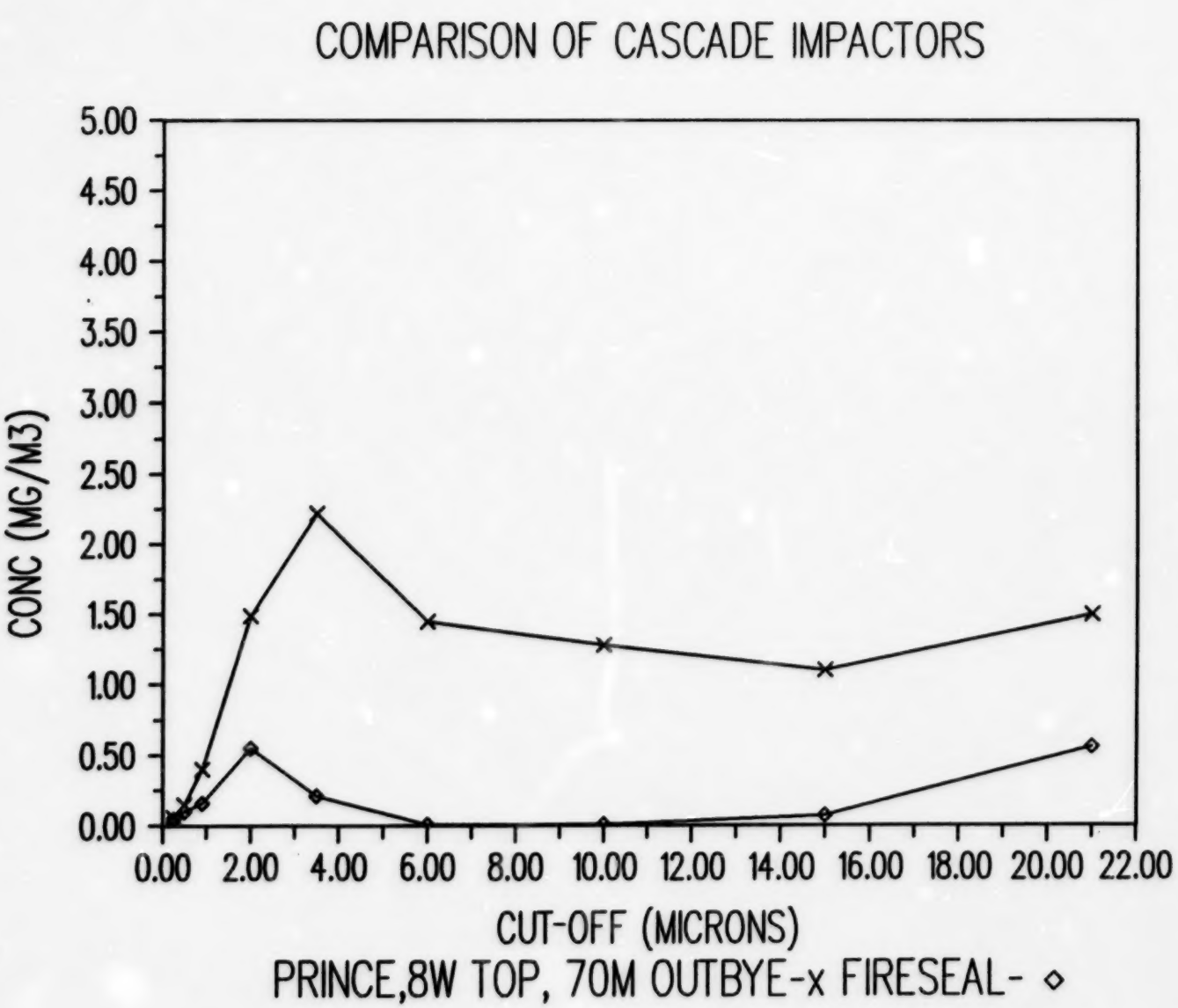

Figure 10 - Dust concentration (mg/m^3) vs 'cut-off' for the Cascade Impactors - Prince 8 West return, November 8, 1989

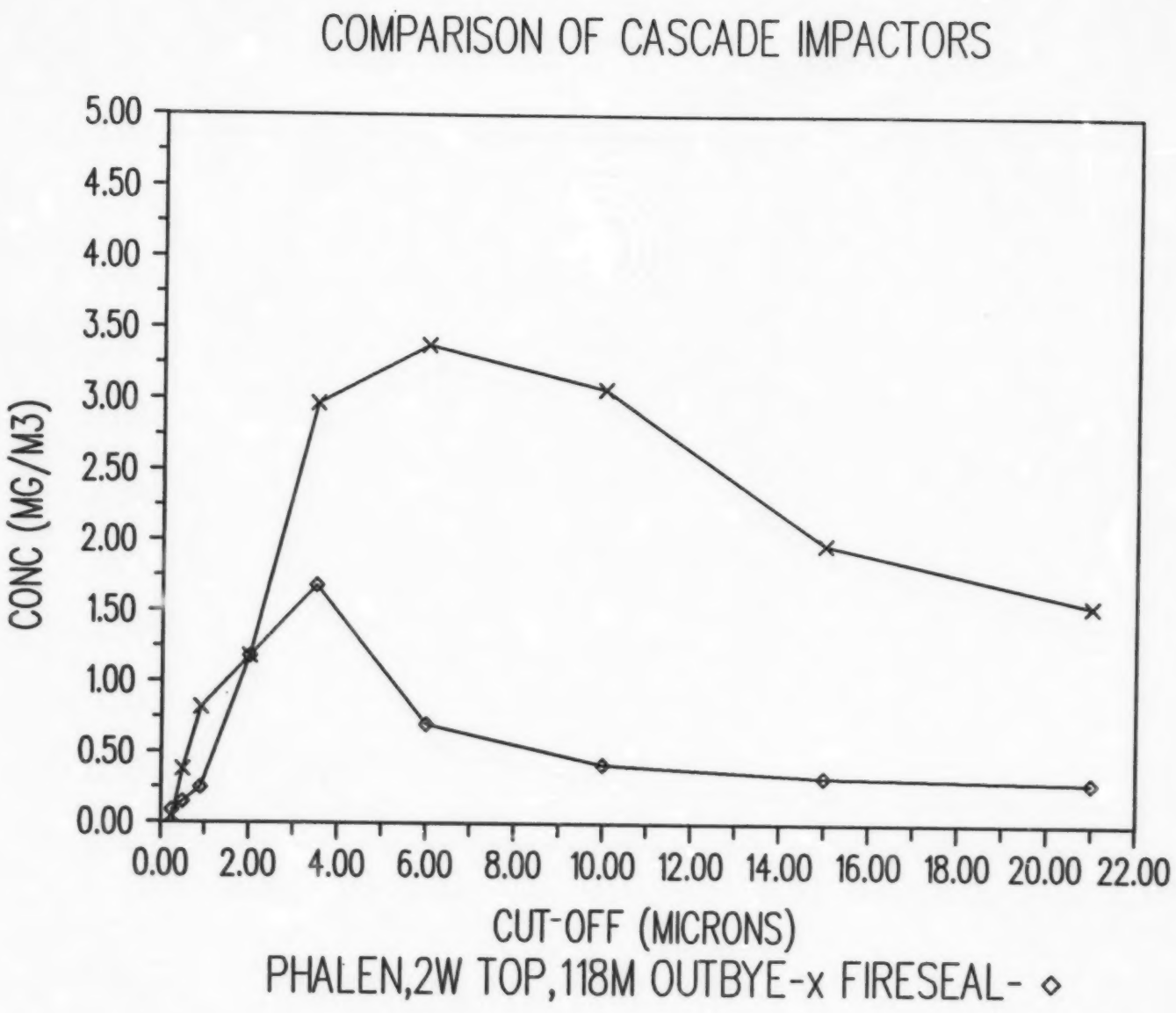

Figure 11 - Dust concentration (mg/m^3) vs 'cut-off' for the Cascade Impactors - Phalen 2 West return, December 5, 1989

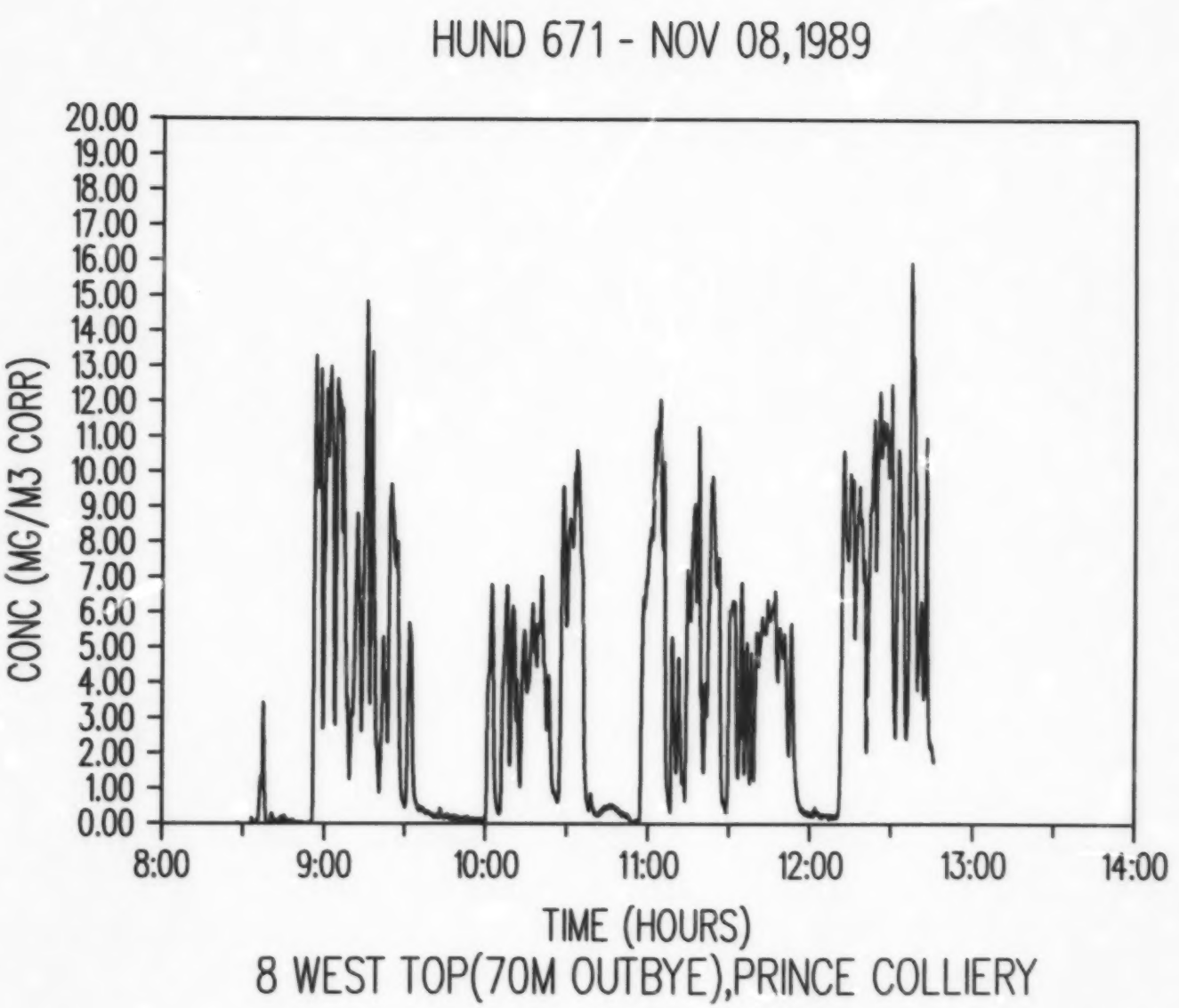

Figure 12 - Real-time respirable dust concentrations obtained from Hund 671 - Station #1, Prince 8 West return, November 8, 1989

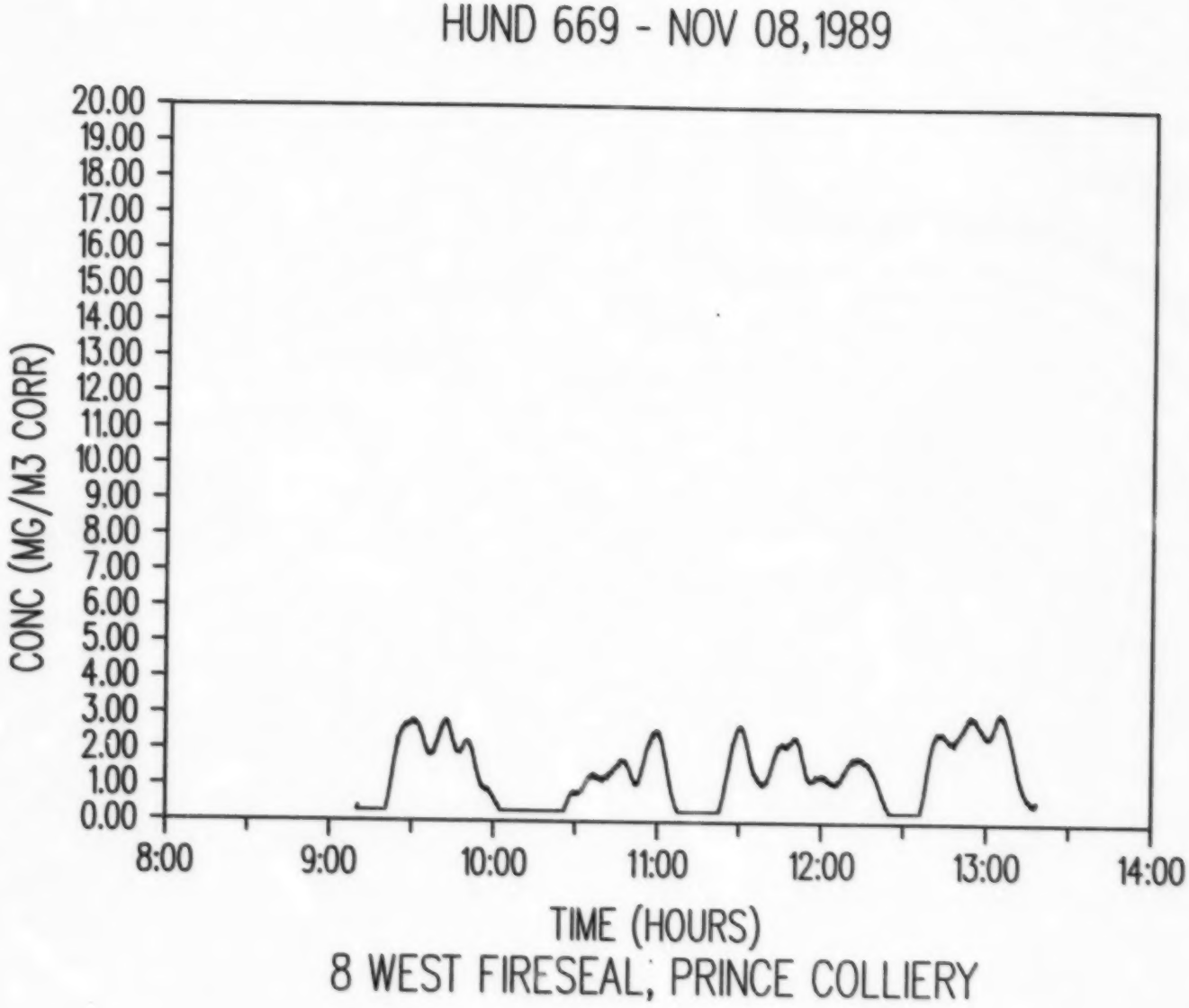

Figure 13 - Real-time respirable dust concentrations obtained from Hund 669 - Station #5, Prince 8 West return, November 8, 1989

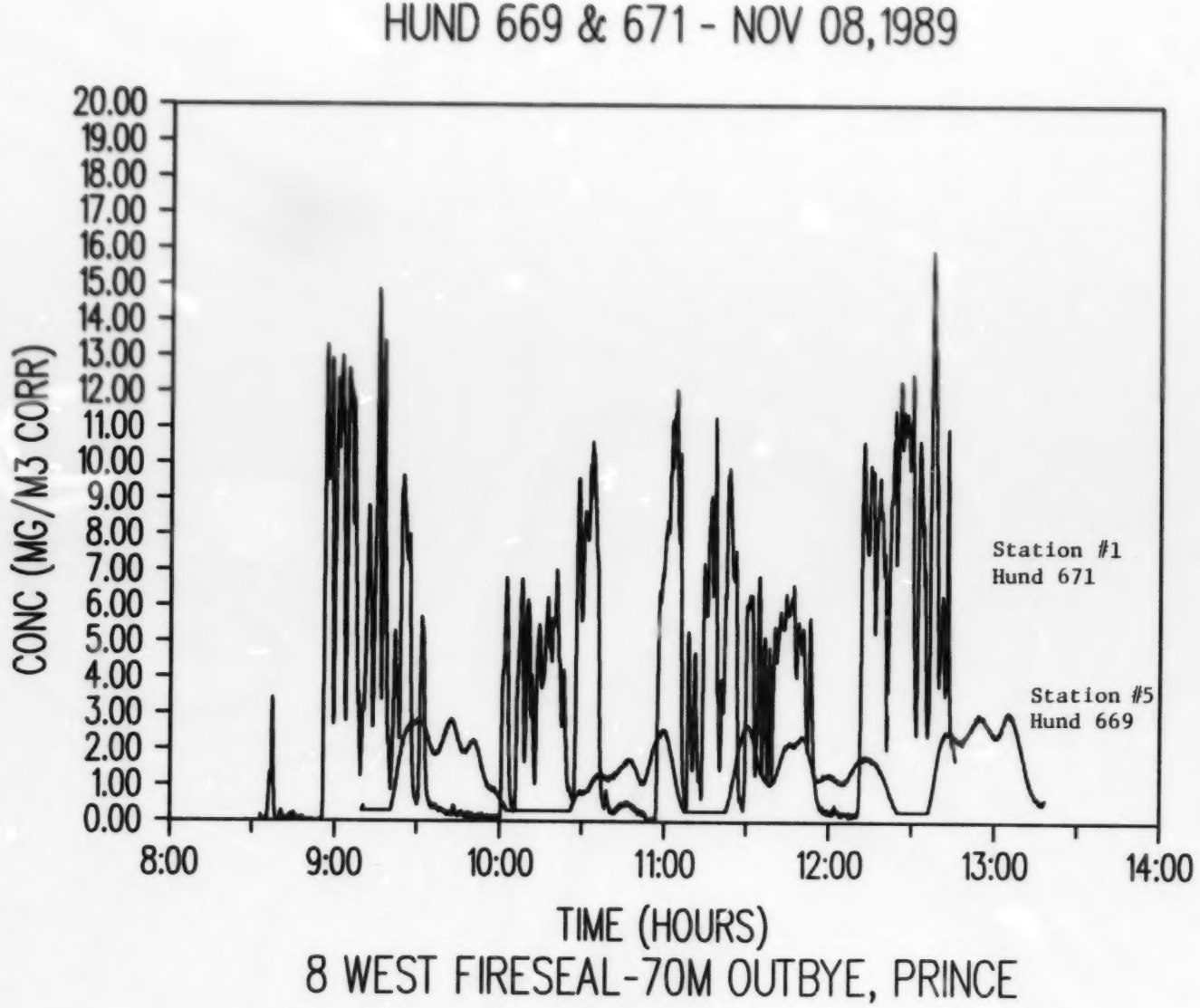

Figure 14 - Real-time respirable dust concentrations obtained from Hund 671 and Hund 669 - Station #1 and Station #5, Prince 8 West return, November 8, 1989

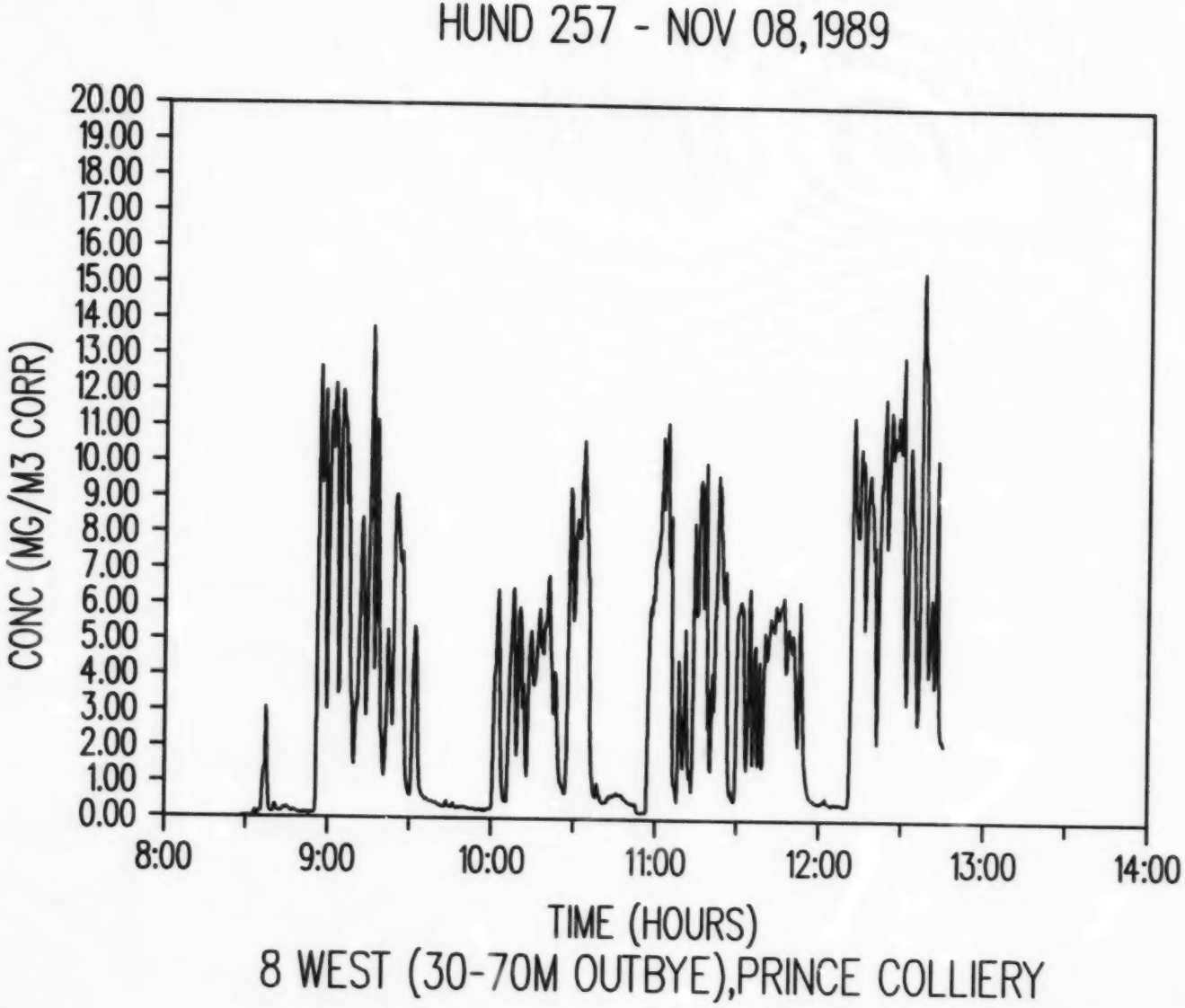

Figure 15 - Real-time respirable dust concentrations obtained from Hund 257 - 30-70 m outbye, Prince 8 West return, November 8, 1989

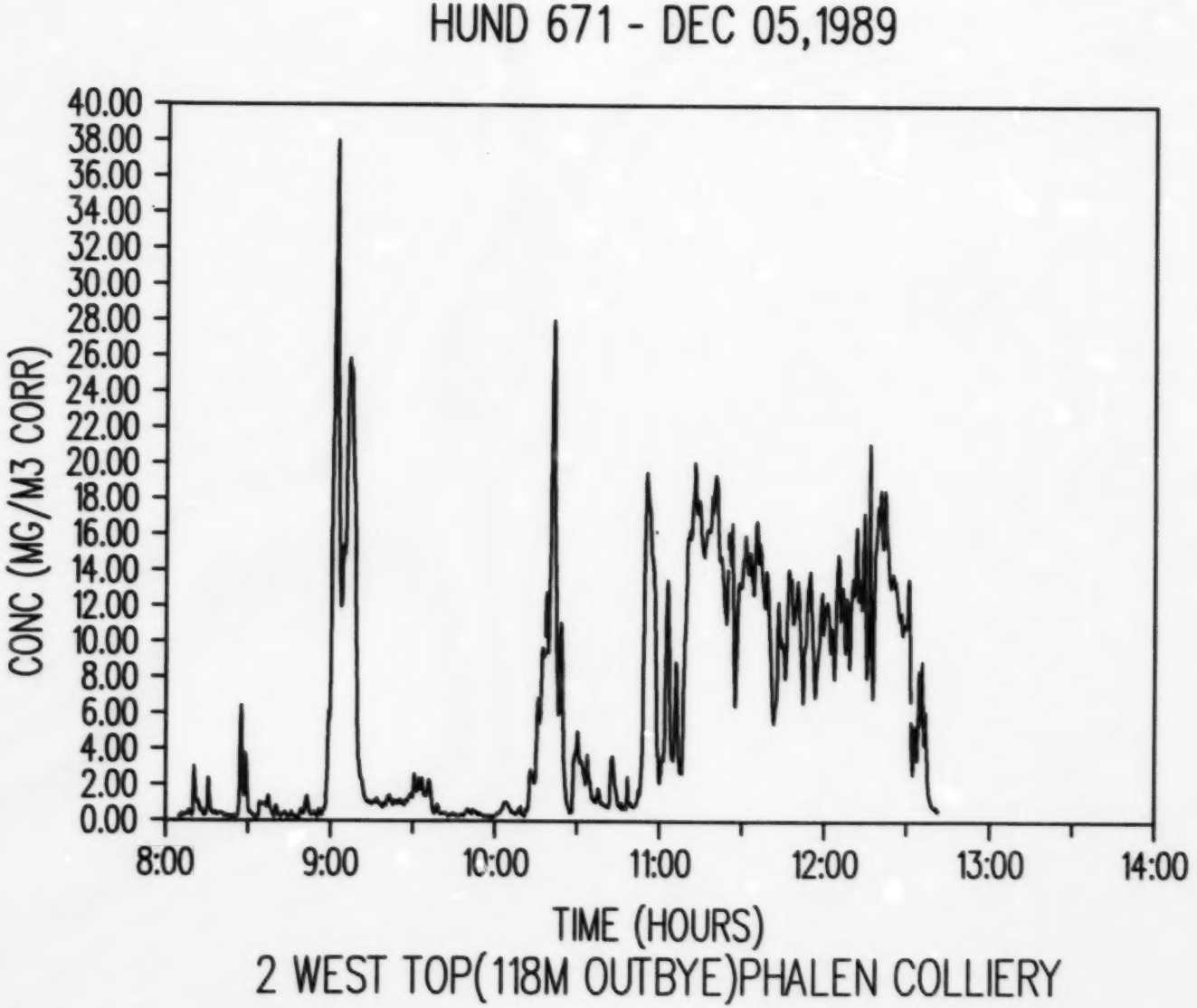

Figure 16 - Real-time respirable dust concentrations obtained from Hund 671 - Station #1, Phalen 2 West return, December 5, 1989

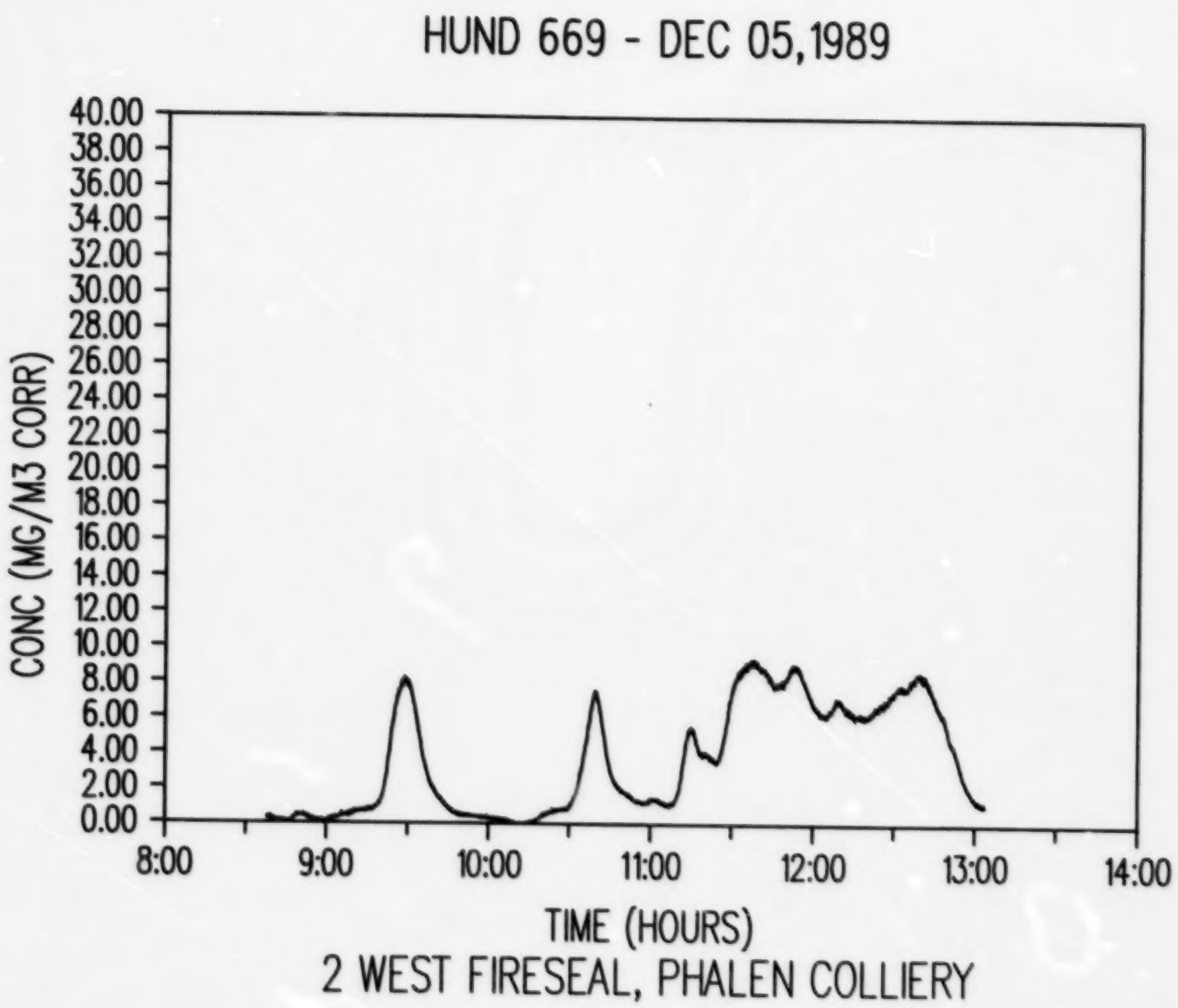

Figure 17 - Real-time respirable dust concentrations obtained from Hund 669 - Station #5, Phalen 2 West return, December 5, 1989

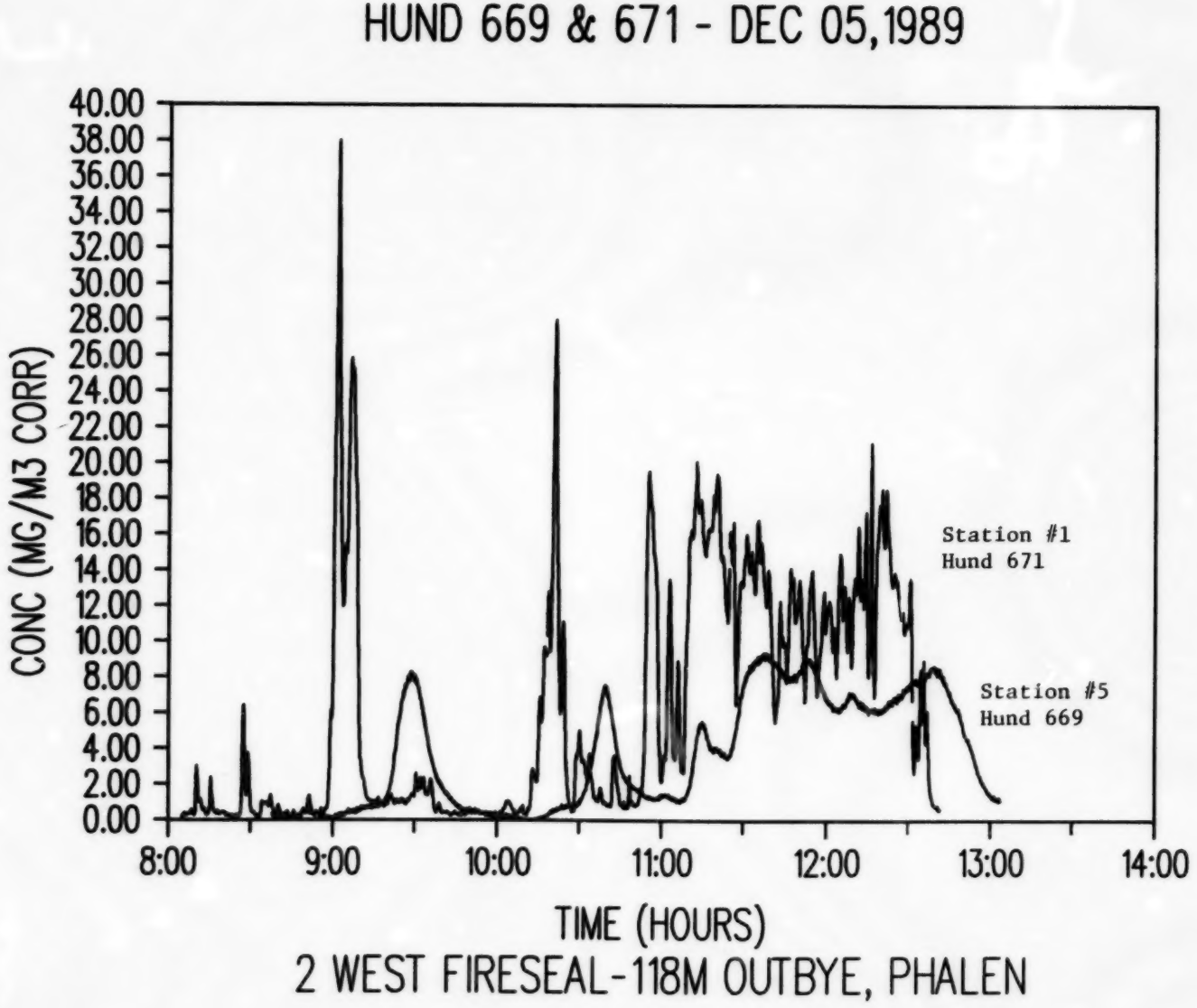

Figure 18 - Real-time respirable dust concentrations obtained from Hund 671 and Hund 669 - Station #1 and Station #5, Phalen 2 West return, December 5, 1989

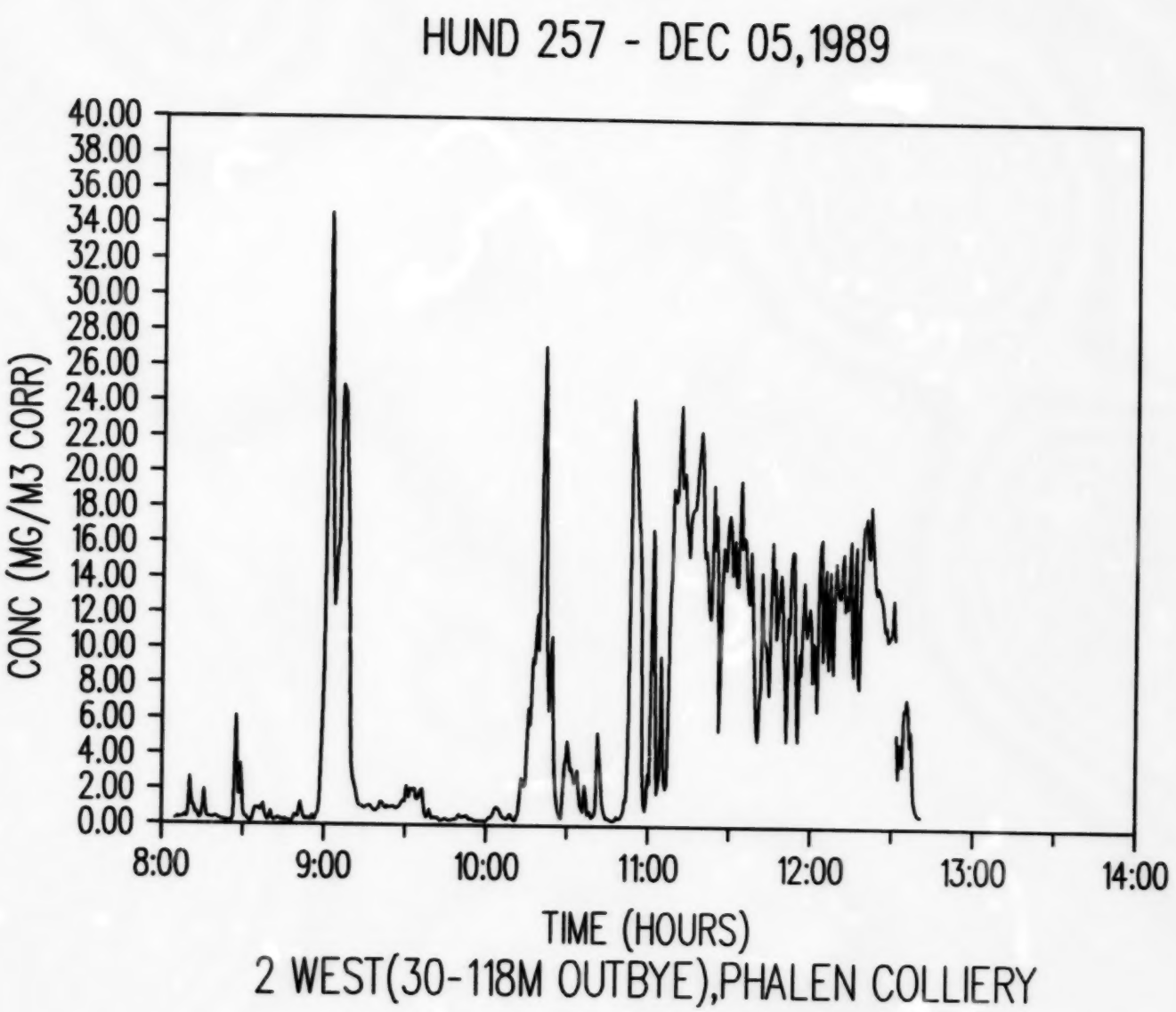

Figure 19 - Real-time respirable dust concentrations obtained from Hund 257 - 30-118 m outbye, Phalen 2 West return, December 5, 1989

were corrected to the average concentration obtained using the Casella SIMPEDS cyclones with constant flow pumps. Relative respirable dust concentrations for the entire sampling period can be observed and correlated to the 'dust generating activities'. Table 9 shows the wall activities recorded during the Phalen 2 West survey (no observations were recorded during the Prince 8 West survey since the conveyor system is located on the intake roadway). Figures 16 and 17 present the real-time dust concentrations for Station #1 and Station #5 respectively for the Phalen survey.

Figures 15 and 19 present the real-time dust concentrations obtained from Hund 257. This dust monitor was set up next to Hund 671 for a period of time near the beginning and the end of each survey shift to obtain a correlation factor. These Hund 257 concentrations were then corrected to the average concentration obtained using the Casella SIMPEDS cyclones as previously noted. The Hund 257 was then moved to several different locations such as 30 m outbye, to the middle of the roadway at Station #1 and to the low side of the rib at Station #1. This was done in order to compare dust levels at these locations vs Station #1 and to give an indication of how close to the statutory control point a remote dust monitoring system has to be to give acceptable or equivalent results. Tables 10a and 10b present the location and the concentration values for both Hund 671 at Station #1 and Hund 257 when it was moved to the different locations noted above. Data is presented for both the Prince and Phalen dust surveys.

VENTILATION MEASUREMENTS

PRINCE SURVEY

Anemometer readings were taken approximately 15 m inbye fireseal (9:20 a.m.)(rectangular steel standing supports):

133 m/min	avg. velocity = 2.18 m/sec
127 m/min	area of roadway = 8.33 m^2
132 m/min	air quantity = 18.14 m^3/sec (38,430 cfm)

Table 9 - Wall activities at Phalen 2 West return, December 5, 1989

Full Loading of Coal on Belt		Light Loading of Coal on Belt		No Coal on Belt		Conveyor System Down		COMMENTS
FROM	TO	FROM	TO	FROM	TO	FROM	TO	
						Begin Survey	8:34	
		8:34	8:37					
						8:37	8:57	
8:57	9:14							Visibly dusty
				9:14	9:18			
						9:18	9:19	
				9:19	9:32			
		9:32	9:34					
9:34	9:36							
						9:36	10:11	
				10:11	10:15			
10:15	10:22							Very dusty - poor visibility
		10:22	10:23					
10:23	10:25							
				10:25	10:26			
						10:26	10:32	
				10:32	10:42			Wall & stageloader down
		10:42	10:44					
				10:44	10:51			Wall & stageloader down
		10:51	10:53					
10:53	10:57							Very dusty
				10:57	11:00			Wall & stageloader down
11:00	11:02							
				11:02	11:03			Wall & stageloader down
11:03	11:06							
		11:06	11:07					
				11:07	11:08			

Table 9 Cont'd - Wall activities at Phalen 2 West return, December 5, 1989

Full Loading of Coal on Belt		Light Loading of Coal on Belt		No Coal on Belt		Conveyor System Down		COMMENTS
FROM	TO	FROM	TO	FROM	TO	FROM	TO	
11:08	11:26							Very dusty
		11:26	11:28					
11:28	11:41							
		11:41	11:44					
11:44	12:02							
		12:02	12:03					
12:03	12:17							
		12:17	12:19					
12:19	12:31							
						12:31	12:34	
		12:34	12:35					
				12:35	12:38			
						12:38	12:47	
				12:47	12:48			Reversing the belt
						12:48	12:51	
				12:51	12:57			
						12:57	End Survey	

Notes: a) Full Loading of Coal on Belt - Cutting Coal
b) Light Loading of Coal on Belt - Snaking and Cleaning
c) No Coal on Belt - No Coal Cutting
d) Conveyor System Down - No Coal Cutting

Table 10a - Respirable dust concentrations for Hund 257 and Hund 671 - Prince 8 West return, November 8, 1989

	Hund 671 - Respirable Dust Conc. (corr) mg/m^3 Station #1, 70 m outbye High Side of Rib	Hund 257 - Respirable Dust Concentration (corr) mg/m^3	Location of Hund 257	Sampling Duration (min)
1	3.18	3.18	70 m outbye, high side of rib	125
2	3.75	3.59	30 m outbye, high side of rib	54
3	4.53	4.45	70 m outbye, high side of rib	23
4	3.80	4.12	70 m outbye, middle of roadway	33
5	9.04	9.28	70 m outbye, low side of rib	14
6	4.67	4.99	70 m outbye, high side of rib	7

Table 10b - Respirable dust concentrations for Hund 257 and Hund 671 - Phalen 2 West return, December 5, 1989

	Hund 671 - Respirable Dust Conc. (corr) mg/m^3 Station #1, 118 m outbye High Side of Rib	Hund 257 - Respirable Dust Concentration (corr) mg/m^3	Location of Hund 257	Sampling Duration (min)
1	2.97	2.96	118 m outbye, high side of rib	148
2	9.92	10.76	30 m outbye, high side of rib (just downwind from or outbye stageloader)	92
3	10.29	10.46	118 m outbye, high side of rib	32

Anemometer readings were taken approximately 70 m outbye wall (10:20 a.m.) (rectangular steel standing supports):

144 m/min
147 m/min
146 m/min

avg. velocity = 2.43 m/sec
area of roadway = 7.19 m^2
air quantity = 17.46 m^3/sec (36,971 cfm)

Temperature in the return was approximately 16°C and the air was saturated with moisture (almost foggy). It took an average of approximately 25 minutes for the ventilation air to travel from Station #1 to Station #5.

PHALEN SURVEY

Anemometer readings were taken approximately 400 m outbye wall (10:20 a.m.) (trapezoidal steel standing supports):

119 m/min
128 m/min
125 m/min

avg. velocity = 2.07 m/sec
area of roadway = 12.06 - 1.06 (conveyor assembly)
= approximately 11.0 m^2
air quantity = 22.77 m^3/sec (48,000 cfm)

Note: Air velocity (quantity) was somewhat erratic during the shift, e.g. at approximately 400 m outbye (10:00 a.m.) the avg. air velocity was 0.44 m/sec (air quantity = 4.83 m^3/sec). This was probably due to an open door somewhere in the district which enabled the ventilation to 'short circuit' for a period of time.

Air velocity readings were taken approximately 25 m inbye the fireseal:

65.5 m/min
66.0 m/min

avg. velocity = 1.10 m/sec

The roof here was too high to allow us to get a height measurement without something to stand on (ladder). The 'arched steel standing supports' run for only a short distance (not quite to the first 'manhole'). Beyond this point, the roof is supported by the 'trapezoidal steel standing supports'.

Temperature in the return was approximately 20°C and the relative humidity >95%. It took approximately 15-20 minutes for the ventilation air to travel from Station #1 to Station #5.

DISCUSSION AND CONCLUSIONS

The results from the two surveys conducted at Prince and Phalen Collieries clearly indicate a significant drop in respirable dust concentrations from approximately 70 m outbye (Station #1) to the fireseal (Station #5). The Casella SIMPEDS cyclone fitted with constant flow pumps gave excellent duplicate results for the five sampling stations and the average values of these sampling systems are used in Figures 3 to 5. It should also be noted that these are the same results that would have been attained using the Casella Type 113A (6).

In Prince 8 West return only 34.6% of the respirable dust reached Station #5 (fireseal) from Station #1 (70 m outbye wall), i.e. 66.4% was lost through either settling or impaction. In Phalen 2 West return only 59.2% of the respirable dust reached Station #5 (fireseal) from Station #1 (118 m outbye wall), i.e. 40.8% was lost through either settling or impaction.

The information provided by the Casella SIMPEDS cyclones is further supported by the results obtained from the 'Marple' cascade impactors (Figures 10 and 11). In addition, for the Prince surveys virtually all the coarse non-respirable dust (i.e. >8 μm) was lost by the time it reached Station #5 at the fireseal. The relatively high concentration of the first stage cut-point at 21 microns is probably due to contamination, i.e. dust may have fallen into the impactor as it was being positioned at the beginning of the survey and/or taken down at the end of the survey. The same trend is also present for Phalen, however it is not quite so dramatic as that of Prince. Some of the reasons for this will be discussed below.

Although both surveys show the same general trend, the dust settling/impaction rate was higher at Prince. Possible explanations for this are as follows:

a) The Prince 8 West return roadway was significantly longer than that of Phalen 2 West.

b) Phalen 2 West has the electrical transformers, conveyor system, stageloader, etc. in the return roadway. Prince has this equipment in the intake. The conveyor system can be expected to generate a certain amount of both respirable and non-respirable dust all the way out to the fireseal.

c) Prince 8 West return roadway is wetter and cooler than Phalen 2 West return roadway (the ventilation air in Prince 8 West return roadway is saturated with moisture to the point that it is almost foggy). Dust particles tend to act as "condensation centres" for moisture under these elevated humidity conditions and can promote dust settling. In addition, dust particles impacting on any surface in Prince 8 West return roadway would have an increased probability of adhering to these surfaces simply due to everything being so wet. Phalen 2 West return roadway is dryer and it can be expected that particles impacting on any surface may bounce off and perhaps even dislodge other particles.

The effects of electrostatic attraction between the dust particles and exposed surfaces in the roadway are not known; however, it is expected that they are minimal, again due to the high moisture levels.

It is expected that air velocities play a critical role in the quantity of respirable dust which makes it to the fireseal. The air velocities at both Prince and Phalen were similar; Prince approximately 2.30 m/sec and Phalen approximately 2.07 m/sec. Because both air velocities were similar it was not possible to assess what a difference in air velocity would have on dust concentrations measured at the fireseal. However, it is expected that a higher velocity would promote increased impaction rates whereas lower velocity would promote increased settling rates.

Real-time dust concentrations obtained using the Hunds are included in this report. The wall activities for Phalen are also given and can be directly correlated to the dust concentrations measured by the Hunds. Note that the Hund graphs from Station #5 are offset due to the time that it took the ventilation air to reach Station #5 from Station #1. This is an example

of the type of detailed information which could be instantly available if a remote dust monitoring system was installed.

If a remote dust monitoring system was to be set up in the return of a retreat longwall district, the dust sensor would have to be set up at the 70 m outbye (statutory control point) in order to directly assess dust levels emanating from the wall. This would necessitate moving the monitor as the face advanced. Measurements taken with the Hund dust monitors indicated that dust concentrations varied little when moved to the 30 m outbye position, to the middle of the roadway or to the opposite rib (<10% variation for the Prince and Phalen surveys). Higher variations would be expected at Phalen due to the conveyor/stageloader assembly just inbye or upwind from the 30 m outbye position.

The dust sensor could be situated at the fireseal, however an equation would have to be used to correct the measured concentration. This equation would have to consider the distance that the dust must travel. A 'second order polynominal' was used to 'curve fit' the data in Figure 5b. A factor or first order polynominal cannot be used because the dust decrease as measured was not linear. Ideally, a range of concentration values and varying conditions (involving several surveys) would be required to produce an equation to determine or predict the dust concentration at the 70 m outbye position for each district and colliery. To actually calculate the dust levels at the 70 m outbye position: a) enter into the equation 'distance from the fireseal (in meters)' and solve the equation and b) divide the dust concentration value obtained at the fireseal by the '% respirable dust'.

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